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The Ecology of Maine's Intertidal Habitats : A Report Prepared for the Maine State Planning Office

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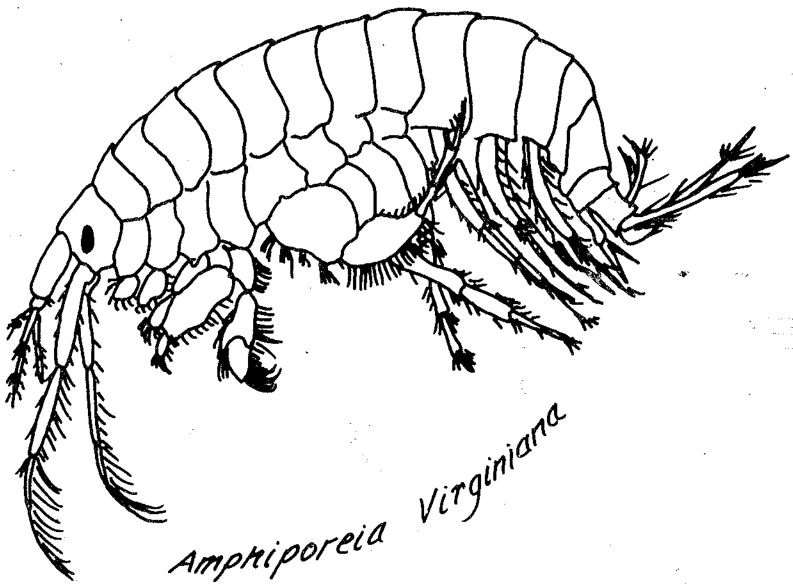

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THE ECOLOGY OF MAINE'S INTERTIDAL HABITATS

A Report Prepared for the

Maine State Planning Office

By

Bigelow Laboratory for Ocean Sciences

West Boothbay Harbor, Maine

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CHAPTER 1

INTRODUCTION

The relationships between the land and the sea, the two great masses that form the surface of the earth, are both complex and dynamic. This is obvious to anyone who has ever watched the rise and fall of the tide or the violence of a winter storm. The purpose of this handbook is to present a synthesis of information on certain ecological aspects of the land-sea interaction as they pertain to the Maine coast. In particular, the kinds of animals living between the tide lines, the intertidal zone, are documented, and the relationship between these animals and their environment, both natural and perturbed is discussed.

World-wide, there is a wealth of information on the intertidal zone and the organisms and activities which occur there. The first investigations in the field of marine science must have occurred thousands of years ago in the intertidal zone because of its accessibility to man at low tide. Today, the intertidal zone in general is probably the most widely known of the marine environments. For centuries the abundant biological resources at this zone have been harvested by man and untold millions of vacationers, beachcombers and treasure hunters have enjoyed its aesthetic beauty or searched for its hidden riches.

Serious scientific research into the intertidal zone has been carried out with increasing frequency and sophistication for at least a century. Early investigations consisted of descriptions of the animals present and only secondarily commented about the physical, chemical, and biological interactions with which our relatively new science of ecology is concerned. During this early period, amateur shell collectors added significant knowledge on the distribution and habitat preferences of molluscs, a major intertidal group. Later, entire communities of intertidal animals were described. The majority of this work took place in northwestern Europe and in the United Kingdom, where the importance of the intertidal zone as a feeding ground for commercially important fish was, and still is, recognized.

In the United States, thorough investigations of the intertidal zone took place on the Southeast and West Coasts. The West Coast, with its greater diversity of plants and animals attracted the most attention, and much of the accumulated information is presented in the still classic book Between Pacific Tides (Ricketts and Calvin, 1939). In the Eastern United States, most of the coast south of Maine is composed of sand beaches. For this reason, interest in intertidal systems (even as far north as Maine) are based on data generated from North Carolina sandy beaches.

Recently, the intertidal zone has become the research medium of ecologists who wish to use the experimental method to study the interactions between species and the environment in an effort to understand how an ecosystem truly functions. This work began in Scotland, but is now pursued most actively on the West Coast of the United States.

Maine's intertidal areas, which are probably the most varied within the United States, have received little attention in the past. During the developmental phase of this project, a complete and comprehensive review was made of all literature, both published and unpublished, that pertained to Maine's intertidal zone. Much of the material available was not suitable for a characterization of the coast because of very limited geographical coverage, unsuitable sampling design, or questionable quality. It became clear that the intertidal information needed to make management decisions on activities and impacts in the coastal zone would have to be collected by initiating a standardized, systematic survey along the entire length of the coast. Only in this way could we know, for instance, whether all cobble beaches manifest the same fauna, and therefore could be expected to respond similarly to a given impact such as an oil spill.

The results of the survey are described in the remainder of this document. This is followed by a brief introduction to the intertidal zone and the principal ecological factors at work there with a discussion of zonation. A section describing the biology of some selected invertebrate species appears in Chapter 4. The rationale and methodology employed in the field work are discussed next. Chapter 6 considers each of the nine specific habitats investigated, with notes on dominant or unique species and, where appropriate, more generalized descriptions of the habitats from the scientific literature. Included are a cursory review of various man-induced stresses on intertidal communities and populations, and their implications for planning efforts. The extensive detailed data generated by the field program and various analyses are presented in a data report which is designed to be used as a companion document to this one. A glossary of scientific and technical terms is included.

It is our hope that this format makes the handbook both readable and enlightening to the layperson without sacrificing the rigorousness needed by the professional user.

SIGNIFICANCE OF INTERTIDAL RESOURCES

The intertidal zone is one of the most important components of the coastal ecosystem. Its living and non-living resources have both commercial and aesthetic values of great wealth and significance.

The direct harvest of intertidal invertebrates is of major importance to the economy of Maine. The digging of the soft-shelled clam, *Mya arenaria*, and marine worms, both the bloodworm *Glycera dibranchiata* and the sand worm *Nereis virens*, employ thousands of persons in Maine (as diggers, wholesalers, shippers, processors and retailers) and brings millions of dollars a year into the state. Smaller fisheries exist for periwinkles, *Littorina littorea*, and various seaweeds whose extracts are used as food additives.

In many areas of the world the mineral resources of the intertidal zone are mined, but this is not widespread in Maine. There has recently been mining of heavy metals in the Cape Rosier area, and collectors of pet rocks have been a threat to certain cobble beaches. Major disturbances, such as sand mining from sandy beaches and dunes, has not yet been extensive.

The intertidal organisms are also of indirect commercial importance. Fish, particularly the winter flounder, rely heavily on the biota of the intertidal zone for their food. A study conducted in Passamaquoddy Bay (Wells, Steele, and Tyler, 1973) found the following in stomachs of winter flounder which were captured in the intertidal zone: 40% algae, 13% *Peloscolex benedeni* (oligochaete worm), 7% *Nereis virens* (polychaete worm), 3% *Gammarus lawrencianus* (amphipod), 3% *Ampithoe rubricata* (amphipod) and assorted other intertidal species. Percentages are by weight. Lobsters, crabs, and other commercially important species can utilize the intertidal zone at high tide.

Wading birds, gulls, and diving ducks feed almost exclusively in intertidal and shallow subtidal habitats. These birds are certainly of aesthetic importance, and some of them generate economic benefit through their attractiveness to hunters and birdwatchers.

The intertidal zone is a major producer in the coastal ecosystem. Marsh grasses, exported as detritus to adjacent deepwater environments, are a major source of food for many species which are directly or indirectly of economic importance. Like marsh grasses, the large seaweeds such as kelp and rockweed contribute significant amounts of material to the ecosystem. Odum *et al.* (1974) state "intertidal rocky subsystems may be important to the producing, consuming and cycling components of the estuary". The benthic diatoms which live on the surfaces of mud flats may also be very important producers. Warwick (personal communication) believes that the productivity of these diatoms is almost twice that of the phytoplankton in the overlying water.

The growth of plant life in the water is often limited by the availability of inorganic nutrients such as nitrate. Much of the nutrient material in a body of water settles to the bottom attached to sediment particles or as fecal pellets. The benthic fauna then take on significance, because through their activities they return much of the nutrient material to the water column, where it can be utilized by the phytoplankton. The fauna of the intertidal zone undoubtedly contribute to this "nutrient regeneration" process, although this has not been documented.

Aesthetically, intertidal areas are priceless. Besides being areas of great scenic beauty, marshes and other intertidal environments provide needed habitat for birds and mammals.

Sandy beaches are unsurpassed as recreation grounds, and people travel thousands of miles to gaze at the magnificent splendor of Maine's wave-swept, rocky intertidal zone.

CHAPTER 2

HUMAN IMPACT ON INTERTIDAL FAUNA

By definition the intertidal zone is the dynamic interface between land and sea. Since humans have historically been dependent on water, and especially the ocean, for travel, commerce, food resources, and even waste disposal, population centers developed in the coastal zone. Further migration inland took place along rivers, which were used for transportation, power, and waste disposal. The rich land of the river's flood plains was developed into farms that altered the nature of the runoff into the rivers.

The vast majority of human activities, then have a direct or indirect impact on the waters of the coastal zone. These vary from the obvious impact of bulkhead construction in the intertidal zone to the less obvious chronic oil pollution. Alterations in the dissolved and particulate loads of our rivers eventually affect the coastal zone, because all water flows to the sea. Many coastal oceanographers regard estuaries as an avenue where coastal waters are degraded because of the large amount of anthropogenic (man-derived) material passing through them.

Research on the environmental impacts of human activities is being carried out today at an unprecedented rate. Despite these efforts, however, we have only an embryonic knowledge for predicting what impact a given activity will have on a given body of water and its inhabitants. Gross effects can be predicted with some certainty, whereas more subtle or sublethal effects are almost unknown.

Research on environmental impacts has followed two courses. The first is the investigation of an impact in the field. A classic example of this approach is the follow-up study after an oil spill. When the event occurs, scientists rush to the scene and measure as many parameters as possible at affected and control stations; they then return to their labs to analyze the data and deduce the extent of the impact. This sort of "real world" work is essential. The approach, however, has certain limitations. Scientific limitations are due mainly to a lack of prespill data. Nature is never completely constant, so most species exhibit both seasonal and interannual variations in abundance. Unless the natural dynamics of communities are understood, it is difficult to differentiate between natural variations and those due to pollutional stresses. This is why properly planned baseline studies are so important. Baseline studies are expensive, as are the long-term studies that are needed to document fully the impact of a spill or other disturbance. The financial commitment to study the impact of a major spill often must yield to other priorities for public funds.

The second kind of research on environmental impacts is done in the laboratory. There species are subjected to various levels of pollutants to determine their effects on mortality, feeding and respiration rates, reproductive behavior, etc. This approach has two major drawbacks. The first is that it is difficult to extrapolate results of laboratory studies to the environment. An individual may react quite differently to a disturbance while sitting in a flask than it would in its natural burrow. Furthermore, the range of tolerance of a population is always greater than the tolerance of the limited number of individuals that can be tested in the lab. Another shortcoming of laboratory studies is that usually only the most tolerant species are used as experimental animals. It is difficult to keep most marine species in the laboratory, so experimenters use those species which can be maintained. These are, of course, the same species which can withstand considerable environmental abuse, and therefore experimental results based on them are not generally applicable to benthic communities as a whole.

Our understanding of the nature of environmental impacts is best advanced by employing both field and laboratory techniques. The laboratory work supplies information on mechanisms by which specific pollutants operate on a biological system and provides a scale of relative sensitivities of species and life stages. The field work, both before and after a perturbation, is necessary to establish that an environmental change has occurred and to document its short and long-term effects.

To date, comprehensive field studies rigorous enough to evaluate impacts thoroughly are very rare. Most often the studies do not have adequate pre-catastrophe data, do not occur immediately after the impact, and do not follow the recovery process long enough to be sure that recovery has actually occurred. Laboratory studies are far more numerous and deal with a wider range of pollutants and pollutant combinations than field studies. This is possible because of the controlled nature of laboratory studies, i.e. all conditions can be held constant while the factor in question is varied. For the most part, though, we don't know to what degree reactions to pollutants or stresses observed in the lab can be applied or evaluated in the field. For instance, if a certain stress decreases the reproductive potential of a species in the lab by 10%, we do not know if this effect is enough to be ecologically significant to a population in the wild.

The purpose of this chapter is to review the major effects of human activities as they relate to the intertidal communities of Maine. The discussion is general so that the environmental concerns can be communicated without getting lost in a forest of details. Readers interested in more detail should refer to review articles where available and/or contact the authors for specific references.

GENERAL TOLERANCES OF INTERTIDAL ORGANISMS AND HABITATS

As documented later in this report, intertidal organisms are a hardy lot. They live in an inherently stressful environment and therefore have maintained broad limits of tolerance compared to their subtidal relatives. This means that, in general, an intertidal species is more resistant to a given pollutant or stress than a subtidal species. That is, a perturbation of a given magnitude has less effect in the intertidal than in the subtidal zone.

Susceptibility to pollutants is also a function of the energy regime of the habitats. High-energy environments such as rocky shores are quickly cleaned by wave action, so harmful material usually does not get a chance to build up. On the other hand, a sheltered environment such as a mud flat tends to be an area of deposition, where pollutants can accumulate over time. Such areas need special care and protection. Ironically, the most susceptible environments are the least well studied.

PETROLEUM HYDROCARBONS

Acute and chronic oil pollution is the most serious threat facing the intertidal communities of Maine. The foggy, rockbound coast of Maine is a hazardous place for tanker navigation. We have been fortunate that no large spills like the *Torrey Canyon* have occurred in Maine, but one could happen, and Maine's ecologists are not well prepared to evaluate the impact. Maine's climate and habitat diversity make it unique in regard to how severe the effects of an oil spill would be. The present study represents the best baseline that exists for the intertidal zone, but it is not seasonal and, of course, does not include the highly sensitive subtidal environment. The few spills that Maine has suffered have not been comprehensively investigated, and generally impact evaluation has been limited to the tolerant, commercial species. It is not known how long-lasting the effects have been on the highly sensitive and ecologically important smaller fauna or on the recruitment of larval individuals.

Oil can affect marine organisms in several ways, and these have been summarized recently by Boesch, Herschner, and Milgram (1974). These investigators state that oil can kill directly by:

1) coating and asphyxiation,
2) poisoning through direct contact or ingestion,
3) exposure to water-soluble toxic petroleum components,
4) destruction of more sensitive juvenile forms,
5) disruption of body insulation of warm-blooded animals.

They list the indirect harmful effects as:

1) destruction of food sources,
2) synergistic effects that reduce resistance to other stresses,
3) incorporation of carcinogenic and potentially mutagenic chemicals,
4) reduction of reproductive success,
5) disruption of chemical clues essential to survival, reproduction, or feeding.

Asphyxiation is a primary cause of death in the intertidal zone following a spill. Barnacles especially are susceptible if the coating of oil is thicker than their shells are high. The coating of rock surfaces with oil can cause species such as periwinkles to lose their hold on the rock and be washed away by the waves.

Any species which has exposed fleshy parts can be poisoned by direct contact. Poisoning through ingestion is one of the greatest threats to deposit-feeding organisms. These individuals actually pass sediments through their bodies, and if the sediments are coated with oil, they pass this toxic substance through their guts.

Contrary to popular belief, oil and water do mix to a certain extent. Many of the toxic components within the oil become dissolved in water and are passed through the respiratory apparatus of marine organisms.

That the mechanisms discussed in the two preceeding paragraphs do occur has been documented by extensive laboratory studies. Which mechanism is actually operative in a given field situation is more difficult to ascertain, but we know they occur because animals not engulfed in oil still die very quickly. Amphipod crustaceans are especially sensitive to hydrocarbon poisoning, as evidenced by the quick and extensive mortality suffered by them in the West Falmouth oil spill (Howard Sanders, personal communication).

The destruction of juvenile forms is the most significant impact of oil pollution, yet is not well studied. Larval and juvenile forms are usually an order of magnitude more sensitive to oil than adults (Hyland and Schneider, 1976). This means that all of the young of a species can be wiped out while the adults survive. An investigator looking for an impact by examining the adults of tolerant species such as the soft clam *Mya arenaria* may come up with negative results despite the fact that a major catastrophe has occurred.

The significance of larval mortality is that oil persists in fine sediments for a period of years. Although the adult population may survive and even reproduce after an oil spill, the population suffers from a lack of recruitment because the larvae die as soon as they enter the benthic environment.

There has been a lot of publicity given recently to the possibility that certain compounds contained in petroleum hydrocarbons can cause cancerous-like growths in marine organisms. Such growths have been observed in soft clams for oiled environments (Berry and Yevich, 1975; Brown, 1977). The evidence that such growths were caused by the oil remains circumstantial, however, and there is no evidence that these growths lessen an individual's viability in the environment.

Reduction of reproductive success results when fewer gametes are produced or when the larvae formed are less viable than normal larvae. Either case makes fewer larvae available to settle to the benthic environment. This effect is probably not great for intertidal invertebrates compared to the mortality experienced by larval individuals settling on oiled sediments.

The chemical clues used by marine organisms can be disrupted by petroleum hydrocarbons. The most generally reported responses of this type are an inhibition or decrease in feeding, and a decline in the response to sexual pheromones.

DREDGING

Another major activity which affects both intertidal and subtidal benthos is dredging for channel construction or maintenance. Dredging's greatest effect is the removal of natural habitat. The new sediment surfaces exposed are colonized, but in all likelihood, the new community is not as productive as the old. Since most dredging produces an unstable sediment configuration, further deposition occurs, requiring further dredging. Repeated dredging insures that a mature community of long-lived species does not become established in the dredged area.

Dredging can also change current patterns on a local level. Since the nature of sediments is largely due to current speed and direction and benthic organisms respond to the sediments in which they live and feed, changes in currents may alter the local distribution of the benthic fauna.

During dredging the turbidity of the water is increased. The extent of turbidity depends largely on the type of sediment being dredged and the type of dredging employed. The increased turbidity may lead to siltation and burial of organisms in the immediate vicinity of the dredging operation. Some species can cope with burial because they can dig themselves out to maintain their proper relationship to the sediment-water interface, but other species die if buried. Turbidity can also decrease the light penetration in the water column, and therefore reduce primary productivity. This phenomenon is probably not very significant in the intertidal zone.

Dredging in a polluted area can release heavy metals and oxygen-demanding substances held within the sediments. This can cause an oxygen sag, which can kill many species and increase the availability of metals to the organisms.

Disposal of dredge spoils is usually not a major problem in the intertidal zone because they are usually dumped at sea. However, spoil has been deposited on marshes occasionally, which is a major environmental change, especially in Maine, where there are so few marshes. This practice is environmentally costly. The U. S. Army Corps of Engineers has been conducting research on the feasibility of building marshes on dredge spoils, which may be a reasonable solution to the disposal problem when other methods are too expensive.

Intertidal flats and marshes are the habitats most affected by dredging. For both the removal of the habitat is of prime concern. In marshes, alterations in the flushing rates cause increased erosion and slumping of marsh banks.

CONSTRUCTION

The impacts of construction in the intertidal zone are similar to those caused by dredging, i.e., loss of habitat, increased turbidity, remobilization of metals, etc. For the most part these effects are of short duration, and the fauna recovers quickly. This is especially true for the construction phases of roadways or buried pipelines, so long as they do not alter currents or flushing rates.

Bulkhead and pier construction can have long-lasting effects on the intertidal zone. The principal impact of such projects is the loss of valuable intertidal habitat. In addition bulkheads, and especially piers, can change local current patterns and cause scouring of the sediments, which naturally affect the resident fauna.

A less well-documented effect of piers is the shading of the intertidal and shallow subtidal surfaces below them. It has been demonstrated that the benthic diatoms on the surface of mud flats provide twice the productivity of the phytoplankton in the overlying water (Warwick, personal communication). It is not known how significant a given degree of shading is in decreasing this productivity.

SHIPPING AND BOATING

Ship and boat traffic and on-and-off loading affect the intertidal and shallow subtidal zones in numerous ways. These activities require the construction of support facilities, i.e. bulkheads, piers, marinas, etc., which all have an impact on the intertidal zone. Further, they require the loading of fuel in the intertidal zone that, despite the most stringent precautions, always leads to chronic oil pollution from seeps and small spills. It has been estimated that one third of the fuel that an outboard motor uses ends up in the water, and this so-called exhaust water is toxic to benthic invertebrates (Nixon, Oviatt, and Northby, 1973).

Shipping activity also results in the spillage of organic wastes into the water. This can be a problem where there is extensive traffic of large vessels, such as in Portland Harbor, but is probably not significant in other areas, except in confined harbors with intensive small boat activity such as occurs in some Maine harbors during the summer.

Other detrimental effects associated with shipping include chronic spillage of cargo that may be potentially harmful (oil-drilling mud, organic materials, chemicals), and maintenance activities such as cleaning, scraping, and painting.

HEAVY METALS

Researchers have become increasingly aware of the need for studies of the effects of heavy metals on marine organisms because of the high rate at which these potential pollutants are entering our waters from many industrial sources. Between the years 1974 and 1976, no fewer than 233 papers appeared on this subject in scientific journals (Eisler, 1977).

The major interest in heavy metals is concern for human health. Since heavy metals can be accumulated, a person eating contaminated fish and shellfish can develop heavy metal poisoning over a period of time. The Mad Hatter from Lewis Carroll's Alice in Wonderland is a caricature of a person with heavy metal poisoning.

Extensive laboratory studies have shown that marine and estuarine organisms are affected by heavy metals. Lethal levels vary greatly among metals and among species, so no general pattern can be put forward. It does appear, however, that increasing temperature and decreasing salinity both increase a species' sensitivity to metals (Eisler and Hennekey, 1977).

The scientific literature does not contain much information on the effects of heavy metals on natural populations. It is often difficult to separate the impact of metals from that of associated pollutants, and many reports show that populations with a large heavy metal load seem to function quite normally. One of us (Larsen) did research on very productive oyster grounds where the oyster meats were actually green from metal pollution.

Application of laboratory experiments to field situations and the use of indicator organisms for heavy metal pollution is made difficult by the fact that so little is known about the normal physiology of even the most dominant marine species (Eisler, 1977). Research is needed in this direction.

BIOCIDES

The thrust of research in the area of biocides and the marine environment has been at the higher trophic levels, such as birds and fish. While it seems reasonable to assume that these substances are taken up by benthic invertebrates, for the most part they do not cause excessive harm until they are accumulated through biomagnification in the flesh of higher organisms. An exception is the impact of insecticides on crustaceans. Insects and crustaceans are members of the phylum Arthropoda, and, because of this relationship, crustaceans may be very susceptible to insecticides in sufficient concentrations in the marine environment.

IMPOUNDMENT

Impoundment of any intertidal area completely alters the nature of that environment. Impoundment prevents flushing of the area and impedes water circulation within it, preventing the fauna within from receiving food and oxygen and allowing buildup of waste material.

TOXIC SUBSTANCES

Besides hydrocarbons and heavy metals, many industries add countless other toxic substances to the waters. These materials ultimately come into contact with the benthic invertebrates, where they may have an impact. Just what the impact is depends on the substance in question, its concentration, synergistic reactions with other substances, and the types of organisms present.

SEWAGE AND ORGANIC WASTES

The disposal of organic wastes into fresh and marine waters can be a serious problem, especially in populated areas. The primary and initial impact of this activity is nutrient enrichment of the water column. This stimulates phytoplankton production and can result in heavy blooms of plankton. Nutrient enrichment has no direct effect on the benthos, but an indirect impact can occur in enclosed bodies of water if the plankton bloom causes the level of dissolved oxygen to fall.

The benthos can be affected by the deposition of rich organic wastes in the area of a sewage outfall. These wastes can actually smother the benthos if the sedimentation rate is high enough, and they can change the chemical nature of the sediments. The deposition of oxygen-demanding substances makes the sediments anoxic right to the sediment-water interface, and sometimes such as on warm days, the overlying water may also become anoxic. This can kill the less tolerant organisms, depending on the length of the period of anoxia. Recent research has shown, however, that some marine invertebrates can continue to metabolize in the absence of oxygen for a limited period of time.

The effluent from treatment plants contains more than organic wastes. Much material, such as hydrocarbons, chemicals, and heavy metals, are passed unaltered through the plant to the environment.

The outflow from storm sewers can have a significant impact on the benthos. These sewers route rain water and meltwater from roadways and parking lots to the nearest body of water. Sometimes this water passes through a treatment plant, but most often it passes straight to the dumping site. This water is not as "pure as the driven snow" that it once was; it contains petroleum hydrocarbons and other chemicals which have been washed off paved areas, and it affects the marine benthos accordingly.

RECREATIONAL ACTIVITIES

The recreational use of the intertidal zone is concentrated on sandy beaches. These are high-energy dynamic environments and are well suited for use by beach-goers and fishermen. Even recreational vehicles do no great harm to the beach face proper. It is the dune area that is the fragile element of a beach system.

Gravel, cobble, and boulder beaches are inappropriate for most recreational uses, and therefore do not receive much pressure.

Sand flats and mud flats are used for the recreational digging of clams, but not for much else. The intensity of this activity is small relative to the commercial efforts discussed below and can be dismissed as a minor impact.

High-intensity foot traffic can be a problem on rocky shores and marshes. Foot traffic on rocky shores crushes the epifaunal animals. Furthermore, human activity usually means that rocks are turned over and not replaced, leaving animals requiring dampness and shelter exposed to the sun and waves. Collecting trips to accessible rocky shores by well-intentioned educational groups can leave these areas, especially tide pools, denuded of their diverse fauna. For this reason, some states and the National Park Service require permits for sampling.

Foot traffic on marshes damages the plants and the marsh surface itself, which in turn increases erosion and the slumping of creek banks. The attendant fauna are removed by these processes.

THERMAL EFFECTS

Marine water can be heated or cooled by industrial processes. Heating the water usually has the most serious effect, especially in areas where the fauna are living close to their upper thermal limit, which is probably the case for some Maine species (Larsen, unpublished). In general, the effect of thermal loading is greatest in the subtidal environment because subtidal organisms have a narrower thermal tolerance than intertidal species.

The effect of cooled water, such as that occurring around a liquid natural gas plant, it not well studied. The most important impact is probably that the temperatures needed for spawning of some species are no longer reached. This affects those species with southern affinities in the immediate vicinity of the plant.

OTHER IMPACTS

In this section, three unresearched phenomena relevant to Maine are discussed.

Tidal power seems to be coming into vogue, and the Canadians will soon begin construction on a plant. No one really knows what the impact will be on benthic communities, but there are several areas of concern. The obvious one includes the impoundment effects, changes in currents, changes in temperature regimes, and passage of organisms through the turbines. Beyond these, however, are the more subtle effects, such as changes in tidal amplitude and, more importantly, possible changes in the tidal rhythm.

Commercial digging for clams and worms overturns large portions of the surface of mud flats and clam flats. This exposes burrowing organisms and juvenile individuals to the summer sun, rain, and winter cold. It is not known how damaging commercial activities are, but it may be that they are harming the very species they are exploiting.

Recent changes in water pollution laws have resulted in the installation of many individual sewage treatment plants that use chlorination in the treatment process. Chlorine is very toxic, and improper management of treatment plants has caused major fish kills; however, little is known about the impact of chlorine compounds on benthic invertebrates.

CHAPTER 3

A PRIMER OF INTERTIDAL ECOLOGY

Ecology is defined as the study of the relationships between living organisms and their environment. In the most general sense, this includes all aspects of human endeavor, for man is only another of the thousands of plant and animal species. Such an all-encompassing definition has little use, however, so the term ecology is most often used with a modifier, such as human ecology, terrestrial ecology, plant ecology, or intertidal ecology. This compartmentalizes the discipline into subunits of narrow enough breadth that they can be reasonably well handled.

The natural laws which govern life as we know it apply equally well to all branches of ecology, but each subdivision has certain details, such as the suite of species involved and the principal operative environmental factors, unique unto itself. The intertidal zone owes its very existence to some of these unique factors.

THE INTERTIDAL ZONE

The intertidal zone is most simply defined as the area between the high and low tide lines. This definition is not sufficient for our purposes, however, since the tides have a complex cycle which does not allow for a single low tide or high tide line to be demarcated. Furthermore, the biological boundaries of the zone, while very strongly influenced by the tides, can often be narrower or wider than the tidal range because of modifying factors such as wave exposure. Ecologists often make a distinction between the truly physical intertidal zone and the region where the biological assemblages grade from the purely subtidal to the purely terrestrial. The latter region is called the littoral zone. In common parlance, the terms are used interchangeably, but in order to clearly explain the concepts on which this handbook is based, we must differentiate between them at this time. The discussion centers first on the effect of the tides and how organisms respond to tidal cycles: then wave exposure is introduced to show how important this is as a modifying factor.

TIDES

Tides are waves of great wave length generated in fluids by the gravitational pull of heavenly bodies. On the earth, the ocean is the only body of water of sufficient magnitude for significant tidal waves to develop. (These are not to be confused with the destructive "tidal waves" caused by earthquakes, which are not tidal at all.) The strongest influences on our tides are the moon, the sun, and the configuration of land masses.

Due to the pull of the sun and the moon and the rotation of the earth, there are usually two tidal cycles a day, i.e. two high tides and two low tides. Tides occur throughout the ocean, but are most readily seen on shorelines, where the rise and fall of the water intermittently exposes and covers a coastal area. It is this area which is alternately in the realm of the sea and the land that is called the intertidal zone.

Because the moon is constantly changing position relative to the earth, the tidal ranges of these semi-diurnal, or twice-a-day, tides vary. The greatest tidal ranges, called spring tides, occur when the earth, moon, and sun are aligned in space, i.e. at, or usually shortly after, the full moon and the new moon. The smallest tidal ranges, called neap tides, occur when the earth, moon, and sun form a 90° angle, i.e. at the half-moon phase. Since the moon is the dominant driving force of the tides, these spring-neap cycles occur every 28 days. This phenomenon is illustrated in Figure 1.

During the calendar year, the distance between the earth and the sun varies, as does the angle at which the earth "faces" the sun and moon: Therefore there is an annual component to the tidal range. In Maine, the greatest tidal ranges occur at the spring tides during the spring and fall.

Another important component controlling tidal range in Maine is the shape of the Gulf of Maine and the Bay of Fundy. The mean tidal range in Maine varies from about eight feet (2.4m) in Portland to eighteen feet (5.5m) at the eastern extremities. This variation is the result of the resonance of the tidal wave in the constricted eastern Gulf and Bay of Fundy. It is important to remember that, with a given slope of the shore, the intertidal zone is wider where there is a large tidal range than where there is a small tidal range.

With this background, we can now describe the extent of the physical intertidal zone and define some ecologically significant features of tidal variations. Referral to Figure 2 during the discussion will be useful.

The physical intertidal zone is that area between extreme low water on the lowest spring tide of the year to extreme high water on the highest spring tide of the year. The substrate between these extremes is entirely covered by ocean water at least once a year and completely exposed to the atmosphere at least once a year. During periods of neap tides, the tidal range is significantly smaller. During extreme neap tides of the year the sea covers the least area above mean tide level at high tide and exposes the least amount of bottom at low tide.

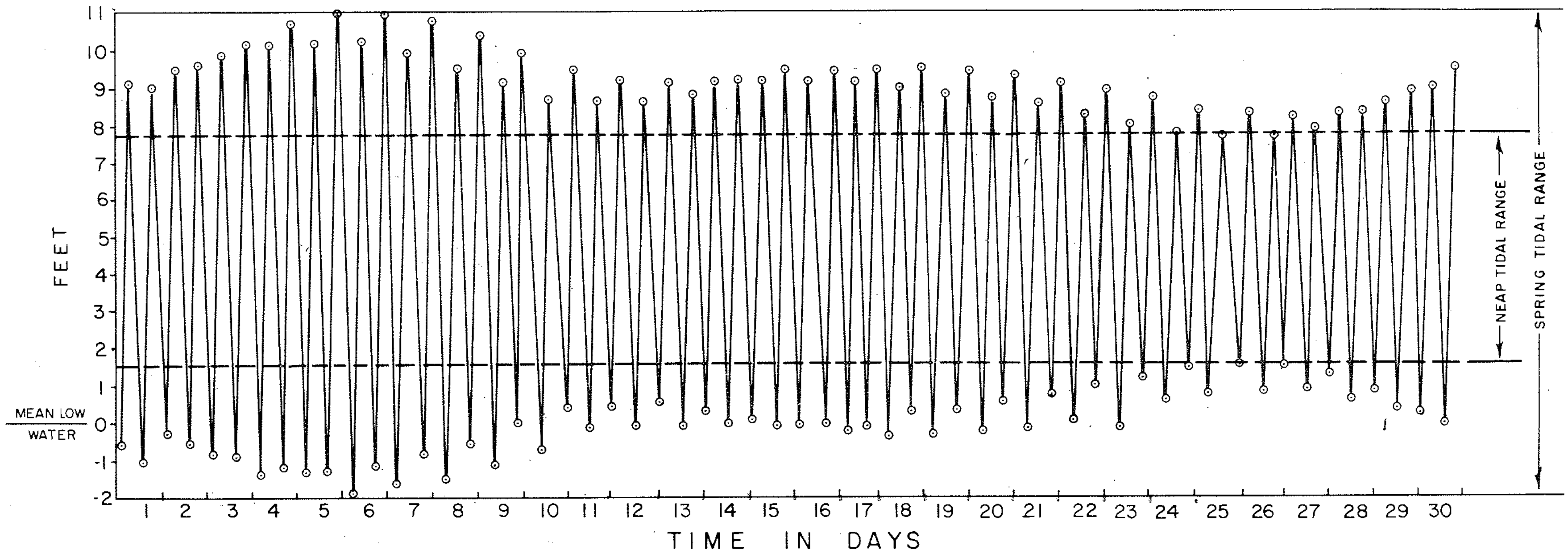

Figure 1. A typical spring-neap tidal cycle drawn from predictions at Portland, Maine, April 1977.

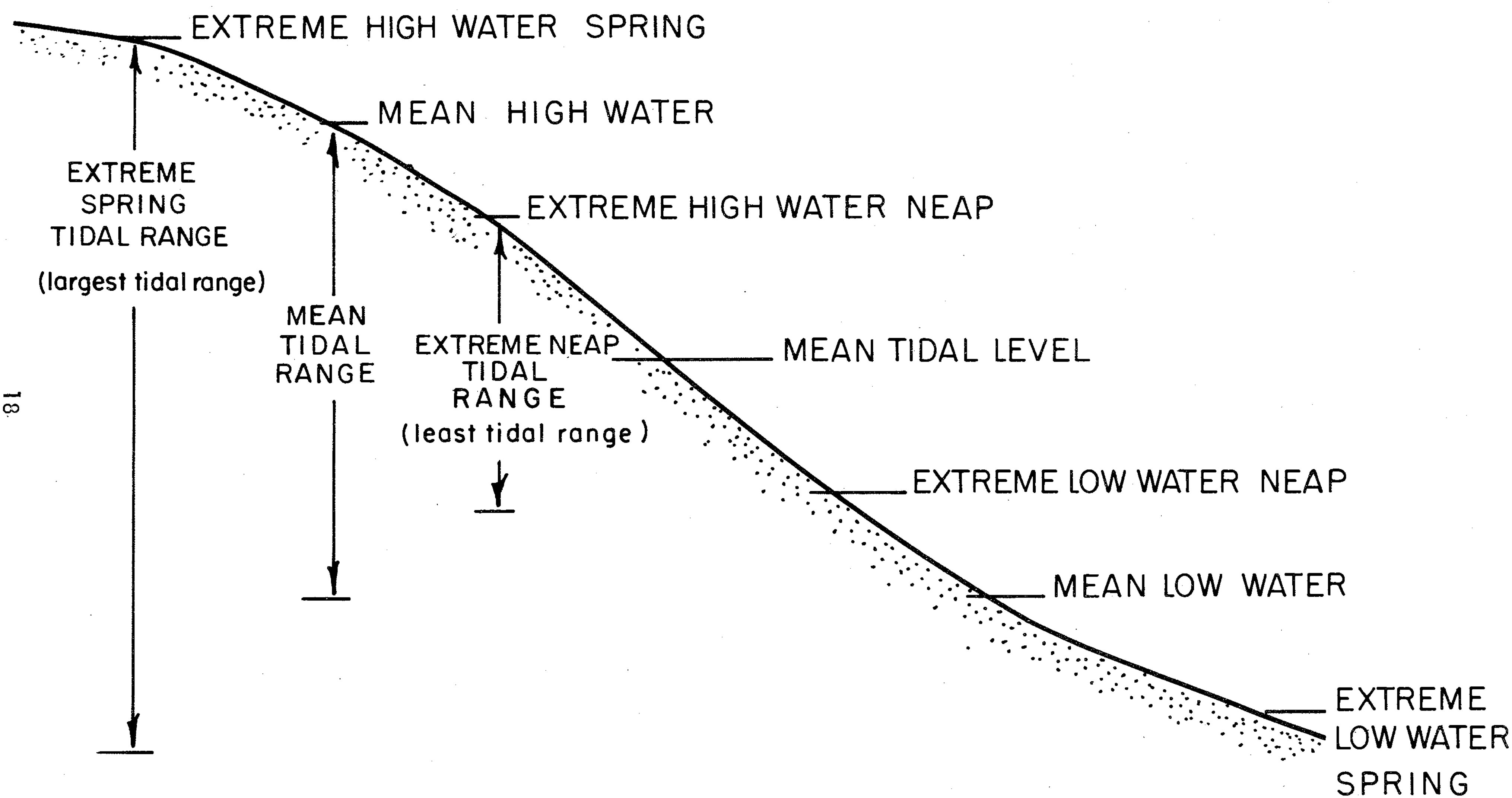

Figure 2. The various tidal levels and ranges discussed in the text.

Most tides, of course, have a range somewhere between extreme spring and extreme neap. For this reason, it is useful to speak in terms of mean high water and mean low water, which simply mean the positions of high and low water on an average tide. Mean tidal level is, of course, the average level of the water.

INTERTIDAL ORGANISMS

It is now necessary to digress for a moment to make some general statements about the organisms found in the intertidal zone.

Intertidal organisms are for the most part, creatures of the sea. Few plant species and even fewer animal species found in the intertidal zone are of terrestrial origin. There are no qualitative differences between individuals found intertidally and those found subtidally, and indeed, intertidal individuals can be considered to be displaced from the subtidal. The reasons for this displacement are given later.

As marine organisms, intertidal biota are as dependent on the sea as are their subtidal allies. This dependence is apparent in all aspects of the organisms' lives, from the supply of food to the removal of wastes, to provision of a medium in which to reproduce and disperse progeny.

The greatest problem faced by any species living in the atmosphere is desiccation. Life began in the sea, and before success could be realized on land, mechanisms had to be evolved that would prevent individuals from simply drying out. (We see the results of this process in internal respiration apparatuses (lungs), impervious external membranes (skin), complex excretory mechanisms which conserve the body's water (by producing urea or uric acid), etc) These adaptions also serve to maintain relatively constant physiological conditions within an individual. The rate of metabolism of marine invertebrate is strongly influenced by environmental temperatures. At colder temperatures, they feed, respire, and grow more slowly than they do at high temperatures. These problems are reduced in the ocean, however, because temperature changes are both small and slow relative to the wide fluctuations which occur on land because of variations in sunlight and air temperatures.

Most marine invertebrates are not greatly advanced in regard to the physiological prevention of desiccation or temperature regulation, and hence they are not well-adapted to being exposed to the atmosphere for considerable lengths of time. Thus, the periodic variations in tidal height are of paramount ecological importance.

THE ECOLOGICAL SIGNIFICANCE OF TIDAL HEIGHT

To how much stress due to desiccation is an organism exposed when it takes up residence in the intertidal zone? Due to the cyclic variations in tidal height, this question can be answered only after knowing at what level on the shore the plant or animal resides. For instance, an individual living between extreme low water spring and mean low water is submerged most of the month and is exposed to the atmosphere on very few days. Conversely, an organism which settles in the upper intertidal between mean high water and extreme high water spring is covered by the tide only on a few days and must withstand several days at a time of continuous exposure to the atmosphere. This is a situation that very few species can tolerate. The ribbed mussel, *Modiolus demissus*, is one such species that occurs in Maine.

Organisms living below mean tidal level, (see Figure 2) are submerged for at least half of each tidal cycle. Those living below mean low water are exposed on only a few days of spring tides each month and hence do not live in an environment greatly different from the subtidal. Between mean low water and extreme low water neap, the organisms receive greater exposure to the atmosphere, but can still be continuously submerged for a few days at a time.

Two points can be made about the organisms living on the shore between the neap tide lines. The first is that these organisms are exposed on every tidal cycle. This means that they must be able to bear the effects of the atmosphere on a regular basis. The second point is that they are inundated by the tide on every tidal cycle. The significance of this is that these organisms do not have to experience atmospheric exposure for more than a few hours at a stretch.

During a given month, the biota residing above extreme high water neap must tolerate extended periods of exposure to atmospheric conditions. Just above extreme high water neap, the time of continuous exposure may be on the order of only 24 hours, but this time increases as the extreme high water spring level is approached. Some ribbed mussels may be reached by the sea on only a couple of tides a month.

THE INTERTIDAL STRESS GRADIENT

The intertidal zone can then be considered a stress gradient running from low stress near extreme low water spring to very high stress near extreme high water spring. Not only does the frequency of atmospheric exposure increase along this gradient, but so does the period of continuous exposure that must be sustained for survival.

During low water periods, the organisms above the low tide level are subjected to stresses that far exceed those ever experienced in the subtidal realm. These conditions include the extreme cold of a winter's night, the extreme heat of a hot summer's day, the extreme drying action of a warm, windy day, and the osmotic stress of a heavy rain (fresh water). Furthermore, intertidal organisms are often dislodged from their substrate by waves and floating debris such as logs that grind across the shoreface with the rise and fall of the tides.

TIMING OF TIDES

The severity of any given stress depends on the time of day at which a low tide occurs. Low tides that occur in the early morning hours during the winter are more likely to freeze the organisms than those at midday. Summer low spring tides that occur in the early afternoon cause greater desiccation than those which happen during the morning or later afternoon. Heavy rains at high tide have no effect on intertidal organisms, whereas a downpour at low tide exposes the same organisms to very low salinities.

WAVE EXPOSURE

On a shore completely protected from wave action, the tides alone determine the extent of the effective intertidal zone. With increased wave exposure, however, the area that can be colonized by a given species is pushed up the shore. This is because the waves break on the shore and wash over, or splash onto, intertidal elevations above the instantaneous sea level, maintaining an adequate level of moisture to prevent desiccation. The larger the waves, the more pronounced the effect.

Figure 3 illustrates this phenomenon, and graphically shows the difference between the physical intertidal zone and the biological littoral zone. At the extreme left of the figure a protected situation is represented. Here the littoral zone is narrower than the intertidal zone. This is the case because the extreme low intertidal zone is occupied by populations which are continuous with those found subtidally. Remember that this portion of the intertidal zone is exposed to the atmosphere only on especially low spring tides. Likewise, the very high intertidal zone is reached by only one or two spring tides a year, and hence marine organisms do not survive there.

With increasing exposure, the littoral zone rises and becomes wider than the intertidal zone. In such areas, subtidal species can occur well into the intertidal zone, and many intertidal species can maintain populations above extreme high water spring.

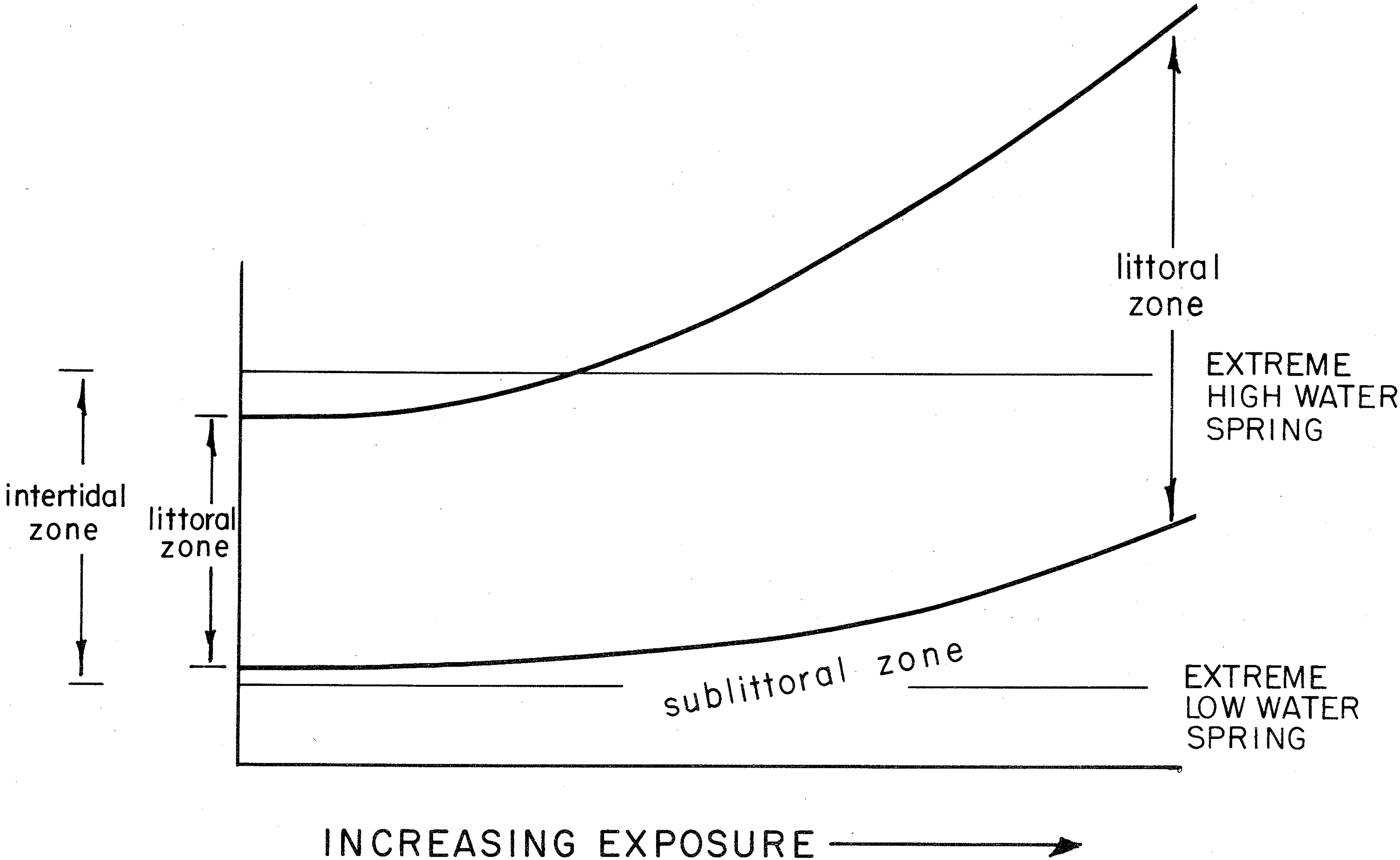

Figure 3. The effect of the degree of wave exposure on the width of the littoral zone.

To avoid confusion between the term littoral and the commonly used term intertidal, from this point on we use only the term intertidal. It is used, however, with the same meaning as the more general, and technically correct term littoral.

OTHER ECOLOGICAL FACTORS

A factor related to the degree of wave exposure is the slope of the shore. The slope of the shore determines how high a wave surges before its energy is dissipated and also how quickly water drains off it.

Flat, wide shores are influenced by wave surge, but, more importantly, the water drains off them very slowly, which lessens the threat of desiccation for the plants and animals living there. As the slope of the shore increases, the effect of surge and splash also increases because of the decreased horizontal width of the intertidal zone. With increased steepness, however, there is also increased drainage. On exposed, rocky shores, the surge effect dominates, and a given species can live at a higher intertidal level than on a flatter shore. In protected areas, however, the rate of drainage becomes the critical factor, and on a very steep shore species are limited to a lower level than normal.

The actual structure of the shore, i.e. what it is made of, is an important factor in controlling what can live on it. Shores of bedrock are very stable, and they can be colonized by any organisms that can establish a firm hold on the rock. In sedimentary environments, the stability of the substrate becomes very significant. For example, some cobble beaches may be quite inhospitable to living organisms because the individual rocks may be moved by waves, especially storm waves, and this crushes most of the organisms which settle on or between them. Likewise, the particles that make up a high-energy sandy beach move with every wave. This environment can be utilized only by fast-burrowing species that can constantly adjust their positions relative to the dynamic sand-water interface.

The composition of the substrate in a sedimentary intertidal area also controls the amount of water that remains in the interstitial spaces at low tide. On a well-sorted sand beach, water drains from between the particles, exposing any organism living there to desiccation and temperature extremes of the air. In sediments of a finer consistency, water remains in the interstitial spaces at low tide, which affords the species living within a degree of insulation against environmental extremes.

Marine organisms are sensitive to reductions in salinity, because in general they do not have sophisticated mechanisms for maintaining a constant internal osmotic balance. When they are put into water of salinity lower than that to which they are acclimated, they swell as the fresher water diffuses into their bodies. Some species have the limited capacity to make adjustments if the salinity change is not too great or too quick. Other species, however, cannot withstand any salinity reduction. These species are excluded from areas which are subject to lowered salinities. Such areas include places where streams cross the intertidal zone, where fresh water seeps in from the water table, and intertidal zones in estuaries. Also included is the intertidal zone during rains. The effect here is greater in the upper parts of the zone, which are, of course, subject to the rain for a longer period of time.

Light is a factor in the intertidal zone much in the same way it is in terrestrial systems. Areas facing south receive more insolation than those facing north, and hence are likely to be drier. The underside of rocks, cracks, crevices, and other shaded places dry out more slowly than exposed surfaces, and therefore individuals living there are less subject to desiccation.

The Maine climate cannot be underestimated in its influence on the development of local intertidal communities. Many species need a certain minimal summer temperature to induce spawning, and if it is not reached in a given year no recruitment takes place. Species with southern affinities often face this problem in Maine. An example is the American oyster, which survives in Maine only in localized pockets of warm water. It appears that the summer water temperatures are lower in the eastern part of the state than in the western section. This means that some species with southern affinities are not able to survive Downeast; if enough species are involved, and if the temperature gradient is sharp enough, a zoogeographic boundary could be defined on the Maine coast.

The seasonal nature of our climate divides the year into a relatively dormant winter period and a productive summer period in which the intertidal biota must grow and reproduce.

There are several ways in which the effects of winter are felt in the intertidal zone. The most obvious is the freezing temperatures. At low tide, the biota are subjected to the freezing of their tissues. The higher in the intertidal that an organism lives, of course, the longer it is exposed to the cold. Ice forms along the shore in protected areas for varying lengths of time each winter. This can be detrimental to intertidal organisms in at least three ways. First, as the tide moves in and out, the chunks of ice grind on the substrate, dislodging many individuals. Secondly, as the ice settles on a tidal flat at low tide, the sediments and organisms can be incorporated right into the ice and floated away during the next tide. In extreme conditions, the water can freeze all the way to the bottom and suffocate everything living there.

ZONATION

The zonation of the intertidal biota into bands parallel to the water line is a general feature along our coast. It is most easily observed on a bedrock shore, where all the organisms are on the substrate surface. Here the shore appears as a series of dark red, brown, white, and black or gray bands going from the subtidal up the shore. The color of the bands is caused by the dominance of certain species. (In our local case, the red is caused by the red algae, *Chondrus crispus*, commonly called Irish moss, while the brown is the result of dominance by one of several brown algae from the genera *Ascophyllum* or *Fucus*, otherwise known as rockweed. The bright white band is made up of a pavement of the barnacle *Balanus balanoides*. The next highest band, often called the black zone, is caused by a film of blue-green algae on the rocks. Although bands of other organisms occur just as sharply, they are either masked by the dominant species described above, or occur within the substrate in sedimentary environments)

The causes of zonation are both physical and biological. The upper limit of the intertidal zone for a given species is controlled by physical factors, and the most important of these are tidal height and wave exposure. Thus, in the intertidal zone from low water up through the different tidal levels, one after another species drops out, and several may drop out at the same point. The points where a number of species cease to exist can be considered upper boundaries of intertidal zones, and these boundaries can be correlated to characteristic levels of the tide as discussed previously. For example, the extreme high water neap tidal level is a physical boundary for those species that cannot tolerate more than a very few hours out of the water.

We can make the generalization that all intertidal organisms are tolerant to environmental stress, and that the higher in the intertidal zone a species is found, the more tolerant it is to stresses such as desiccation, heat, cold, and rain. As the intertidal zone represents a natural stress gradient, species are distributed along the gradient relative to their individual tolerance levels, each being absent above the level at which its tolerance level is reached.

If the upper boundary of a particular zone is set by physical factors, what causes the lower boundary? Certainly it cannot be other physical factors, because intertidal organisms are marine organisms and are capable of thriving in the subtidal environment.

In general, the lower limit of a biological zone within the intertidal zone is set by the biological factors of competition and predation. Species which are successful in harsh or fluctuating environments are generalists and, as such, are adaptable to many conditions. Species evolving in stable environments have become specialized to that environment and are therefore competitively superior to species from other environments. The price they pay for this specialization, however, is a loss of adaptability. Predators are by their nature specialized animals.

Let's take a simple example from the rocky intertidal area to illustrate the phenomenon of zonation. The example is based on the work of Menge (1976), who has elegantly researched the organization of New England rocky intertidal areas, including three sites in Maine. The barnacle *Balanus balanoides* is the dominant species in the upper intertidal zone of rocky shores in Maine, as it is in all of New England and northwestern Europe. Where it is dominant, it forms a solid, wide white band on the upper shore. The upper margin of the barnacle zone exists at the point where the barnacle's tolerance limit to desiccation is reached. This is obvious since barnacles are found in pools and shaded crevices at higher intertidal levels than they are on rock faces (personal observation). Menge has shown that this species can also be successful at low intertidal levels by cleaning these areas of all plants and animals and then observing their colonization by barnacles. Under natural conditions barnacles are not found in abundance at these lower tidal levels, however, because of interactions with two species, the blue mussel, *Mytilus edulis*, and the snail, *Thais lapillus*.

On exposed shores, the lower edge of the barnacle zone is set by the upper end of the intertidal range of the mussel. Within the intertidal area in which both species can live the mussel is competitively superior to the barnacle in the fight for space for attachment. Therefore, the mussel relegates the barnacle to higher levels, where its greater tolerance to desiccation allows it to survive.

On more protected shores, the predatory gastropod *Thais lapillus* preys on both barnacles and mussels. Here the lower edge of the barnacle zone is set by the upper tolerance limit to desiccation of *Thais*. Most barnacles below this level are devoured by *Thais*, and hence the barnacle can occur in abundance only beyond the level that can be reached by *Thais*.

Similar interactions between a species and its physical and biological environment occur throughout the intertidal environment and throughout the world. Most of the interactions are far more complex than the example given, and are very poorly understood. Research in the relatively simple intertidal realm is helping scientists formulate theories about the organization of communities that can be tested and applied to much more complex environments.

CHAPTER 4

A SAMPLER OF INTERTIDAL SPECIES

The intertidal zone of Maine is rich in the number and variety of species which inhabit it. Many of the species occur in several habitats over a wide geographic range. Others are quite specific to a given habitat or location, and some are undoubtedly new to science. In the following paragraphs are presented brief natural history sketches of a few selected species which are ecologically important to our region. Limited time and space, as well as lack of knowledge of detailed life history of a majority of the intertidal residents, make this coverage far from comprehensive.

Mya arenaria (Fig. 4) Soft-shelled clam.

Mya arenaria, commonly known as the soft-shelled clam, is an important commercial and recreational species in New England and the Chesapeake Bay. In Maine, this bivalve is generally harvested in mudflats, but it is also abundant on other substrates such as sand or gravel. It may live subtidally in estuaries and can live throughout most of the intertidal zone; however, it reaches its greatest size in the lower intertidal zone, where its feeding period as a filter feeder is maximized. Its food consists primarily of phytoplankton (free-floating unicellular algae), although there is some evidence of deposit feeding (Rasmussen, 1973).

The spawning season varies along the Maine coast, but is generally from May to September (Ropes and Stickney, 1965). After a two-week planktonic larval stage (which plays an important role in dispersal of the species), the organism settles to the benthic environment and establishes a permanent burrow. Populations of the soft-shelled clam may reach a density of over $300/m^2$ (TRIGOM, 1974). Its most serious competitor is the blue mussel, *Mytilus edulis*, which can overgrow clam beds, and predators include flounder, ducks, horseshoe crabs, green crabs, and moon snails.

Mya is a very hardy creature which can tolerate many environmental insults.

Macoma balthica (Fig. 4 and 5) Baltic clam.

The baltic clam, *Macoma balthica*, is a dominant intertidal species occurring most commonly in mud. In the western Atlantic, its range extends from the Arctic Seas to Georgia, and it occurs throughout the world at similar latitudes. *Macoma* is a deposit feeder feeding on detritus and bacteria, using one siphon like a vacuum cleaner to take sediment from the water-mud interface. Its feces may be recolonized by bacteria and again become a food source for *Macoma* and other

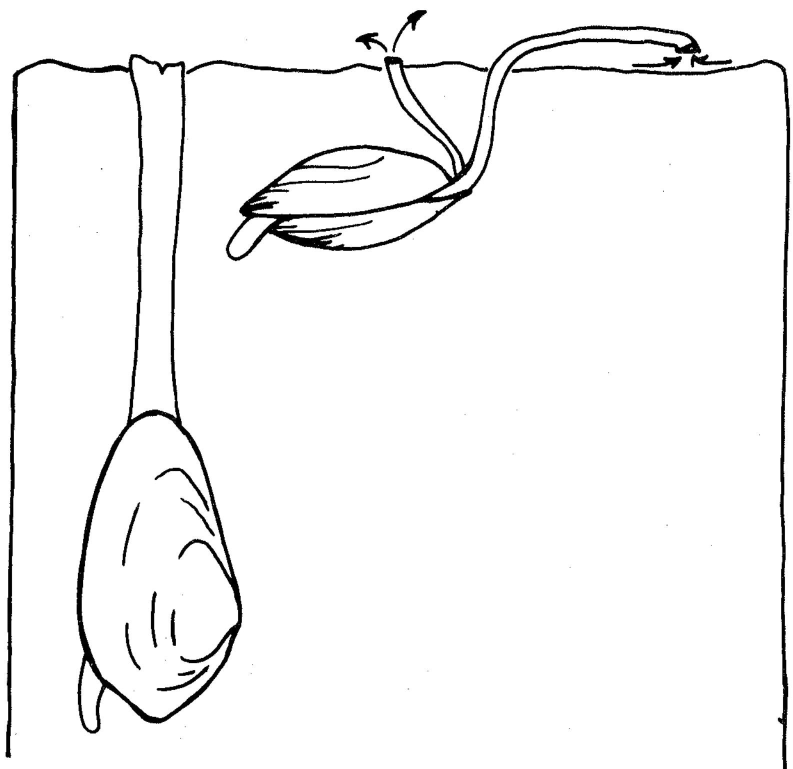

Figure 4. Drawing of *Mya arenaria* (left) and *Macoma balthica* showing their relative positions in the sediment. Arrows illustrate the movement of water and sediment through *Macoma*. Drawing indicates typical relative sizes.

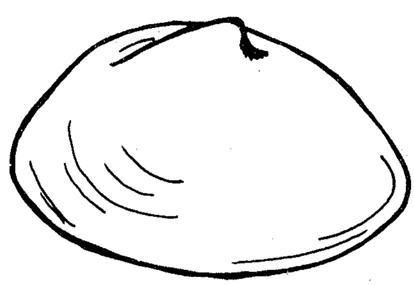

Figure 5. The shell of the baltic clam, *Macoma balthica*, a dominant resident of Maine's intertidal zone.

deposit feeders.

After a 2-5 week planktonic larval stage, the organism settles to the bottom and metamorphoses into an adult. Its primary competitor is the amphipod *Corophium voluntator* (see below), which not only competes for food, but may often prevent successful settlement of the planktonic larvae, thereby disrupting the development cycle of the clam. *Macoma* probably supports a number of predators. The polychaete worm *Nephtys* preys heavily on the young and the adults are eaten by fish and birds.

Thais Lapillus (Fig. 6) Dog whelk.

Thais lapillus, the dog whelk, is a gastropod commonly found on hard substrates in the intertidal zone from Cape Cod to the Bay of Fundy. It is generally white with orange or brown bands, and may reach a length of 30mm. Spawning may occur at any time of the year, and there is no planktonic larval stage. The larvae hatch looking like miniature adults and move to the lower intertidal zone where they feed on polychaete worms and young mussels. As adults, they inhabit a higher area of the intertidal zone and feed primarily on barnacles and adult mussels by boring directly through, or inserting their proboscis into, the shells of their prey. This species often occurs in dense clusters, especially under rockweeds. *Thais* is vulnerable to ice and extreme cold, but it may withstand extended exposure to the atmosphere, although not as long as the barnacle *Balanus balanoides*. Its chief predators are gulls and sandpipers.

Littorina littorea (Fig. 7) Periwinkle

This gastropod species is the common periwinkle, found in great abundance throughout the intertidal zone on both sides of the Atlantic. On the western side, it occurs from Labrador to Maryland. In Maine, it occurs on rocky shores and mud flats, where it grazes on surface films of algae, algal detritus, diatoms, and lichens.

Spawning takes place in February and March, and the larvae are planktonic until May or June, when they settle and undergo metamorphoses. *Littorina* exhibits a daily pattern of migration, towards land at dusk and sea at dawn, which may be adaptive for withstanding long periods of exposure. Gulls and flounders are its chief predators. Competitors for food and space are numerous and include other molluscs, ascidians, barnacles, hydroids, and sponges.

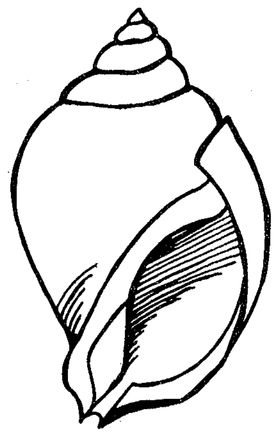

Figure 6. The dog whelk, *Thais lapillus*, a common predator of barnacles and mussels on rocky shores.

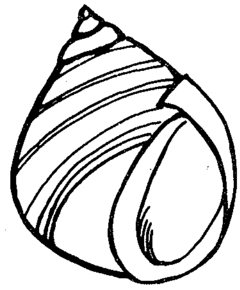

Figure 7. The common and widely distributed perwinkle, *Littorina littorea*.

Corophium volutator (Fig. 8)

Corophium volutator is a tube-dwelling amphipod crustacean found intertidally, especially in estuaries and salt marshes, on both sides of the Atlantic; its range extends from Norway to the Adriatic and the Bay of Fundy to New Hampshire. It is a dominant species in areas with fine-grained sediment, particularly mud. Population densities may be as high as 60,000/m^2. *Corophium* is capable of both deposit feeding (in or out of the burrow) and filter feeding, using its respiratory stream.

Breeding season may vary from early to late spring. Fertilization is external and development is direct, i.e. no free larval stage. The young are brooded by the mother until they resemble small adults, and are then released. Significant predators are shorebirds and flounders, and the major competitor is the polychaete worm *Nereis diversicolor*. Frequently *Corophium* is so abundant that it prevents the successful settlement of the larvae of other species, such as *Macoma balthica*.

Balanus balanoides (Fig. 9) Rock barnacle

The rock barnacle, *Balanus balanoides*, is found abundantly in the upper intertidal zone from the Arctic to Delaware and on the eastern side of the Atlantic. Though covered with several calcareous plates resembling a shell, the barnacle is a crustacean like crabs and amphipods. It attaches permanently to hard substrates, such as rocks, pilings, and boat bottoms, and feeds on phytoplankton, selectively filtering certain types from the water. It is resistent to desiccation and is capable of respiring in air; both qualities make it highly adapted to life in the upper intertidal zone.

The reproductive cycle follows a seasonal pattern. The hermaphroditic barnacles cross-fertilize in the fall and release planktonic larvae in late winter or early spring. These larvae comprise a major portion of the plankton during this time of year. Settlement occurs in early summer and is influenced by several factors, including the nature of the substrate and surrounding fauna.

Predators of the barnacle vary with the stage of the life cycle: herring feed on planktonic larvae, periwinkles on newly settled individuals, and *Thais*, crabs, and polychaetes on adults. There is spatial competition within the species and with other species such as blue mussels, rockweed, colonial tunicates and encrusting bryozoa. In Maine, densities of barnacles have been observed up to 160,000/m^2.

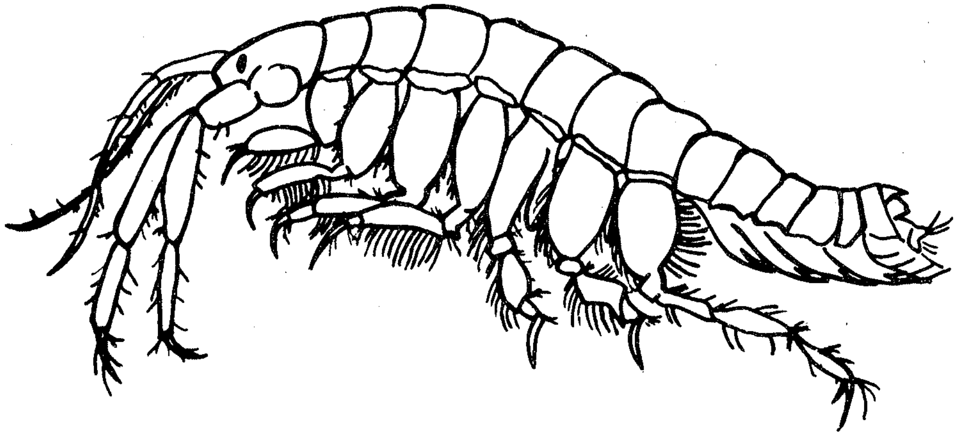

Figure 8. *Corophium volutator*, the dominant amphipod of mud flats in Maine and Europe.

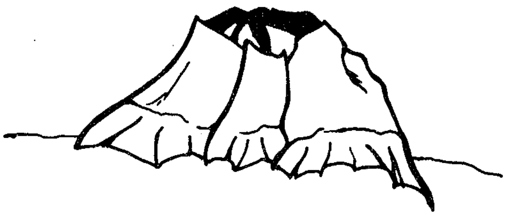

Figure 9. The rock barnacle, *Balanus balanoides*, which reaches densities of up to 160,000/m^2 on rocky shores.

Nereis virens (Fig. 10)

Known as the clam-worm or sandworm, *Nereis virens* is a very commonly occurring polychaete worm in intertidal mud flats, mussel beds, and occasionally subtidally. It may reach a length of about three feet (1m). This species often leaves its burrow at night to swim and feed. As in the case of many polychaetes, feeding methods of *Nereis* may be variable and differ between populations. It has been shown to feed as a predator, herbivore and filter feeder.

Reproduction is somewhat variable. Spawning usually occurs in May, during a new moon, and the worms swarm at the water surface, releasing their gametes. Either pelagic or non-pelagic larvae result, probably depending on local conditions.

Nereis virens is an important food source for fish and crabs, and is also a commercially important species in Maine, as it is utilized as bait for sport fishing. This species can withstand a broad range of salinity and has a wide geographic distribution: Norway to France, Iceland, and Newfoundland to Virginia.

Pectinaria gouldii (Fig. 11)

lower zone

Pectinaria gouldii, the cone worm, is a tube-dwelling polychaete which is often found in intertidal and subtidal soft sediments, especially sand and mud. Its tube is shaped like an ice cream cone which is open at both ends, and it is made of sand grains meticulously cemented together with a mucous secretion. The worm lives head down in the sediment and is a deposit feeder, stripping the diatoms and detritus from the sediments it ingests.

Knowledge of its reproductive cycle is incomplete. Sexes are separate, fertilization is external, and there is a planktonic larval stage. It is preyed upon by fish.

Oligochaetes (Fig. 12)

lower zone

Oligochaetes are a class of annelid, segmented worms which are predominantly terrestrial and aquatic. It has become apparent in recent years, however, that several families of oligochaetes are common marine inhabitants. They may be found from the intertidal zone to the deep ocean in sediment, decaying vegetation, and under rocks. The species under consideration in this study are predominantly burrow-dwellers that feed non-selectively on bottom deposits. Chief competitors are other deposit-feeders, including polychaetes, molluscs, crustaceans, and echinoderms. Oligochaetes are

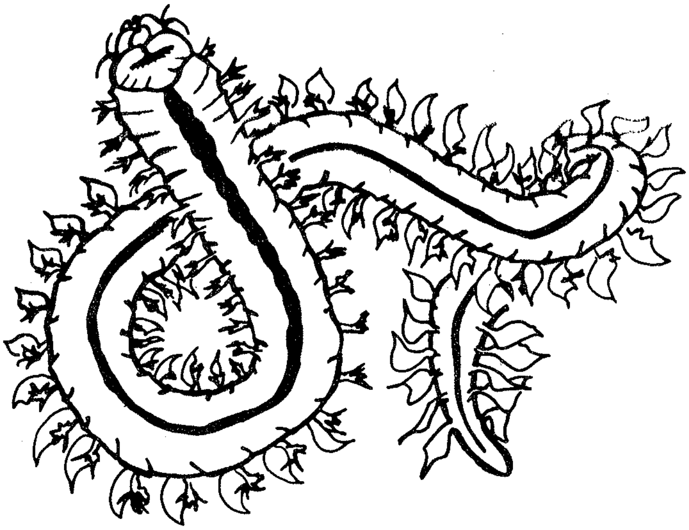

Figure 10. The commercially important sand worm, *Nereis virens*.

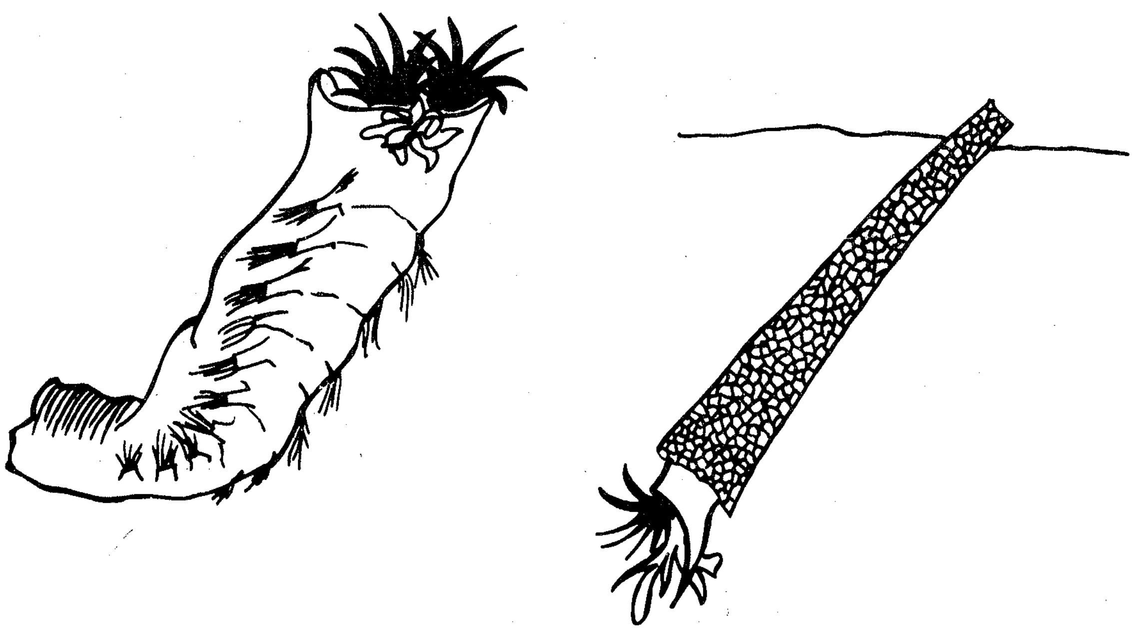

Figure 11. The cone worm, *Pectinaria gouldii*, showing both the worm itself and its natural posture in the sediment.

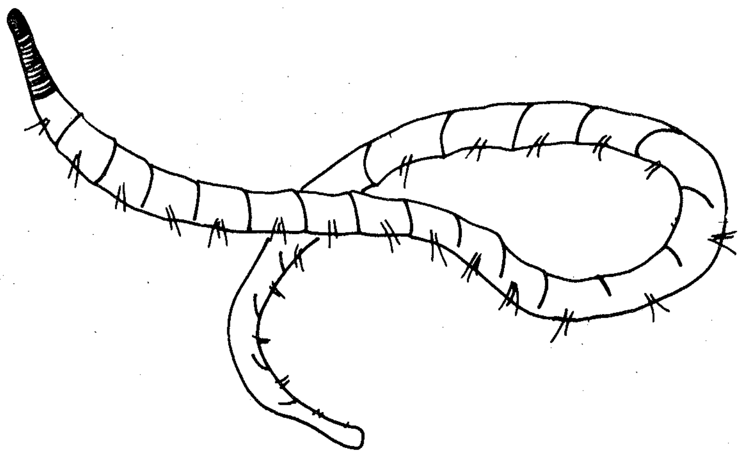

Figure 12. An example of one of the species of oligochaetes which are abundant all along the Maine coast.

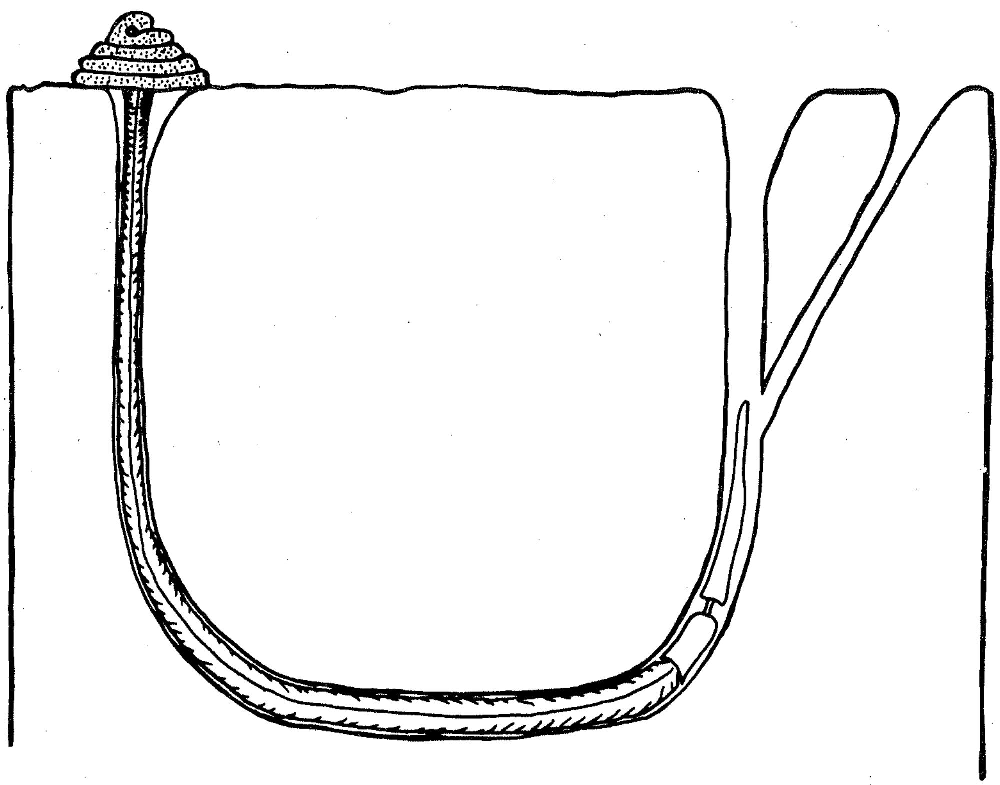

Figure 13. The acorn worm, *Saccoglossus kowalevski*, in a typical burrow showing a characteristic fecal mass.

undoubtedly preyed upon by several species: chief among them is the winter flounder.

Oligochaetes are hermaphroditic and usually undergo cross-fertilization. There is no larval form. In some cases, asexual reproduction by fission may occur. Recent evidence suggests that certain oligochaete species may be important indicators of pollution. Certain populations may become dominant in areas where there is an increase in concentrations of organic matter and decrease in oxygen concentration.

Saccoglossus kowalevski (Fig. 13)

Saccoglossus kowalevski, an acorn worm, lives in local abundance in intertidal and subtidal sand and mud, ranging at least from Maine to North Carolina. It constructs a mucous-lined burrow, open at both ends, from which it extrudes its castings into large piles. It feeds unselectively on the surrounding deposits with its long proboscis. Sexes are separate and fertilization is external. There is no planktonic larval stage. Predators of *Saccoglossus* are not well known, but other species of this group are known to be preyed upon to some extent by crabs and fish.

This group of organisms is not well studied.

CHAPTER 5

METHODOLOGY

RATIONALE

The purpose of this field program is to provide the most reliable picture of faunal distributions and abundances along Maine's 3,500 mile long intertidal zone. Because of the program's financial and time constraints, the sampling program had to be especially well thought out. Since little information existed on intertidal ecology in Maine, we decided that it would be better to obtain extensive data from as much of the coast as possible, rather than intensive data on only a few places. Hence, a habitat approach was chosen.

Using the habitat approach, we selected the nine intertidal habitats that we felt best represented conditions along the coast. These habitats are defined below. Next, we divided the coast into three zones (Kittery to Cape Elizabeth, Cape Elizabeth to the Penobscot River, and the Penobscot River to the St. Croix River), and chose examples of each habitat for sampling in each of three zones. This procedure insured thorough geographical coverage.

For the purposes of describing the intertidal communities of Maine, this sampling design is very strong in two areas; all of the major intertidal habitats have been sampled, and the sampling of most has been coast-wide, which avoids regional bias. It should be possible to extrapolate what we learned from the sites we sampled to other sites of similar habitat type which we did not sample. This is the purpose of every sampling program, and for most of the habitats sampled we have been successful in this regard.

The results of this faunal sampling program are of maximum value when applied in conjunction with the Maine Geological Survey's (MGS) coastal maps, which delineate the distribution of all of the intertidal habitats. For example, if someone wished to get a general idea of what species lived at a particular intertidal location, and that location has not been faunistically sampled, it would be possible to determine from the MGS maps what habitat type existed at the spot. If the habitat were one covered in the faunal sampling, one could conservatively apply the results from the sampled sites to the unsampled site in question. Such extrapolation is tentative and best done by professionals, who can evaluate local environment modifiers. Even then the conclusions must be considered a first, although important, approximation. There is no substitute for site-specific studies.

The sampling design, however, has a major weakness, which is the lack of a seasonal element. Each site could be sampled only once between May and July. (Compared to annual variation, variation within these 3 months is small.) Since only a limited number of samples could be worked up, to have sampled seasonally would have greatly reduced the habitat and geographical coverage. With the data generated, however, we are now in a position to be able to evaluate the seasonal component of species abundance in an efficient manner. If such a seasonal sampling program were instituted, it, in combination with the present faunal sampling program and the MGS maps, would greatly increase our knowledge of intertidal dynamics, and provide a more reliable basis on which to evaluate environmental alterations.

Another limitation is the lack of data from the same sites over a period of years. Communities of organisms experience interannual changes in their species composition and the relative abundance of the component species. As with seasonal changes, the normal range of these interannual variations needs to be defined so that natural and pollutional variations can be more easily differentiated.

HABITAT DEFINITIONS

Many habitats exist along the Maine coast, and it is not possible to devise a habitat classification that adequately describes each. Certain habitats, however, are more widespread and more easily defined and recognized. These are the habitats of greatest biological importance or interest, as evidenced by researchers' attention to them over the decades; i.e., experience has shown them to be ecological units.

On the Maine coast, we have defined nine habitats as worthy of study under this program. Many of the other habitats are simply mixtures or variations of these basic nine and, therefore, some results can be extended to them. Indeed, it should be realized that few habitats are completely homogeneous; for instance, mud flats invariably contain rocks and logs which can be colonized by epifaunal organisms such as barnacles.

High-energy rocky shores are composed of bedrock and are subjected to significant wave action that alters intertidal zonation (Fig. 14). The biota consists of organisms living on the rock surfaces, and dominance is controlled by degree of exposure and biological interactions. Tide pools are often present.

Low-energy rocky shores are composed of bedrock and occur in areas protected from wave action. Rockweed and barnacles are the obvious dominants (Fig. 15).

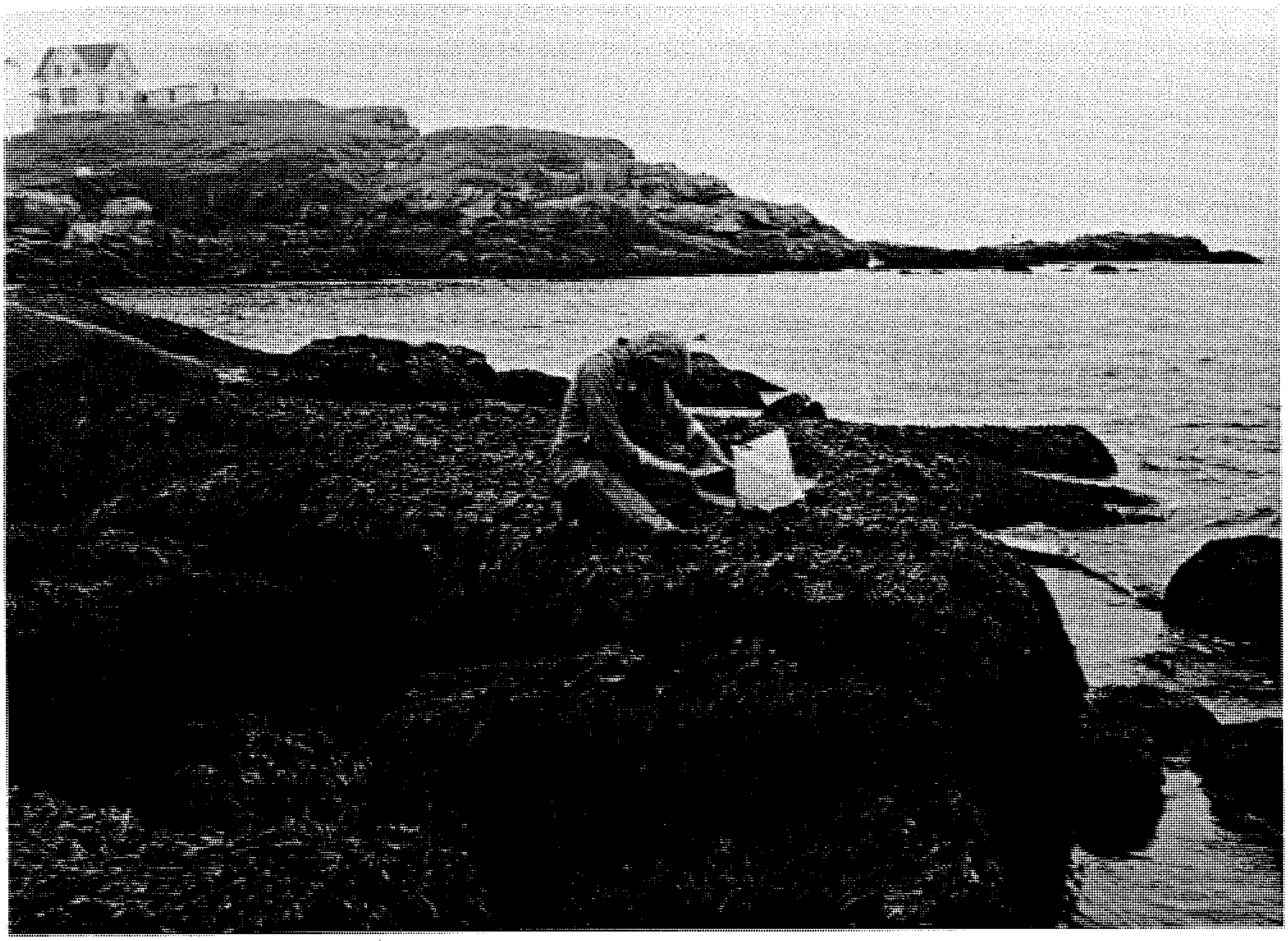

Figure 14. The high-energy rocky shore at Cape Neddick.

Figure 15. A low-energy rocky shore in East Waldoboro.

Boulder beaches are composed mainly of large rocks that are not easily moved by storm waves (Fig. 16). Tide pools and pockets of finer sediment between and underlying the boulders are usually present. Usually macroalgae occur on boulder beaches. Zonation patterns are less well-defined in this habitat. The epifauna dominate, but infauna occur in the sediment pockets and under the rocks.

On cobble beaches, rocks which are large enough to be used as a substrate by the fauna, but small enough to be moved by storm waves, are the predominant inorganic substrate (Fig. 17). Macroalgae are seldom present in this habitat. The growth of epifauna and infauna is often limited by the movement of the cobbles.

Gravel beaches are relatively stable, coarse, sedimentary environments (Fig. 18). They are usually characterized by good percolation that results in a deep anoxic (oxygen-free) layer well below the sediment surface. Macroalgae are not present on the gravel. Infaunal suspension feeders dominate.

Sand beaches are high-energy environments composed of well-sorted sand-sized particles (Fig. 19). The constant movement of the sand on the beach faces limits its utilization as a substrate to a very specialized fauna.

A sand flat is a protected environment predominantly made up of sand, but containing varying percentages of silt, clay, and organic detritus. The flat has a slight grade and often exhibits sand waves (Fig. 20). The fauna present are mainly infaunal suspension feeders.

A mud flat is a very protected environment of predominantly silt and clay mixed with organic detritus (Fig. 21). The flat has only a very slight grade and is anoxic just below the sediment surface. The faunal present are mainly infaunal deposit feeders.

Marsh areas are dominated by thick strands of marsh grasses, most characteristically *Spartina alterniflora* (cord grass) and *S. patens* (salt marsh hay) (Fig. 22). The substrate is a mass of mud, grass roots, and peat.

Figure 16. View along the boulder beach at Roque Bluffs.

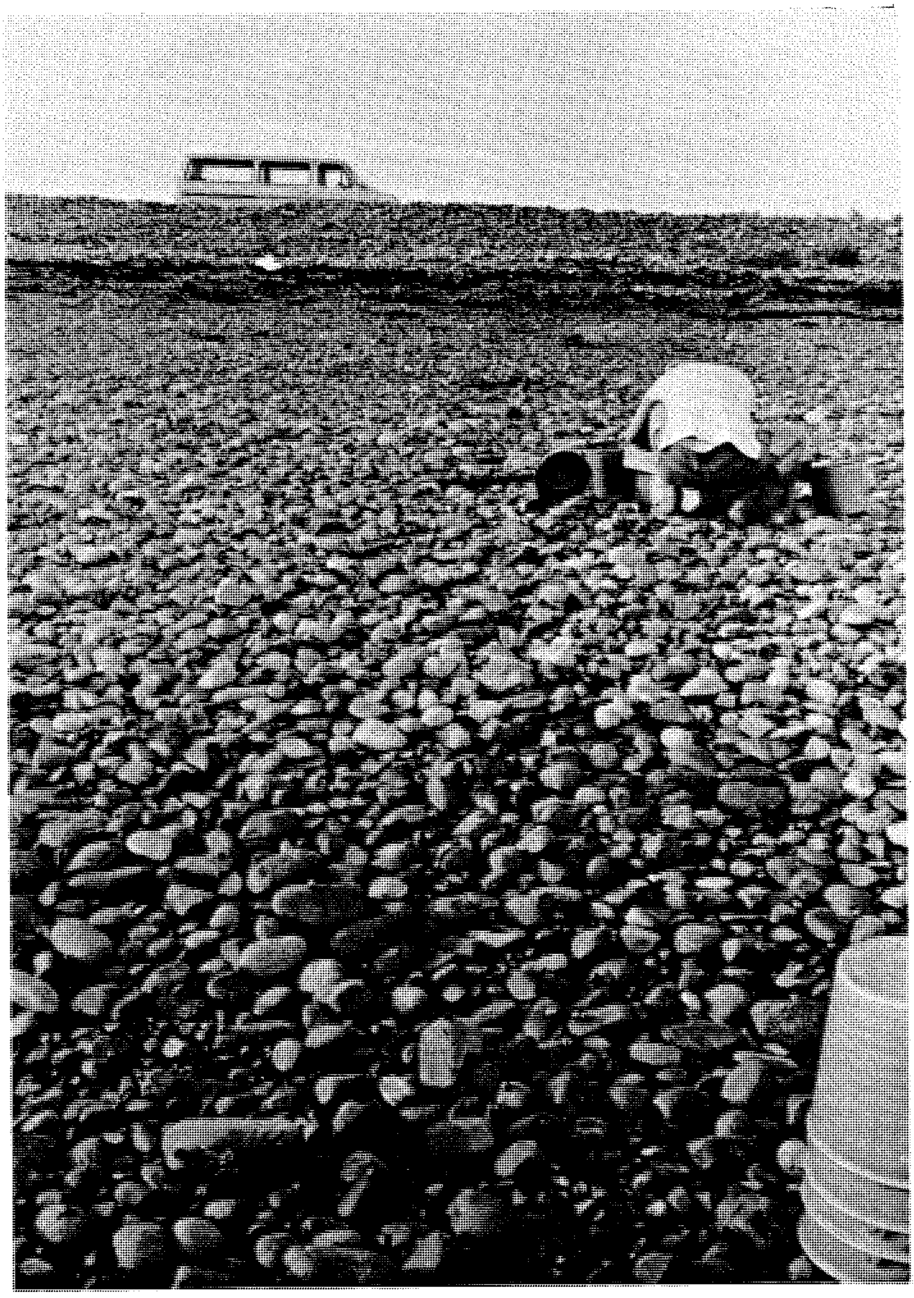

Figure 17. Looking up a transect on a cobble beach at Kennebunkport.

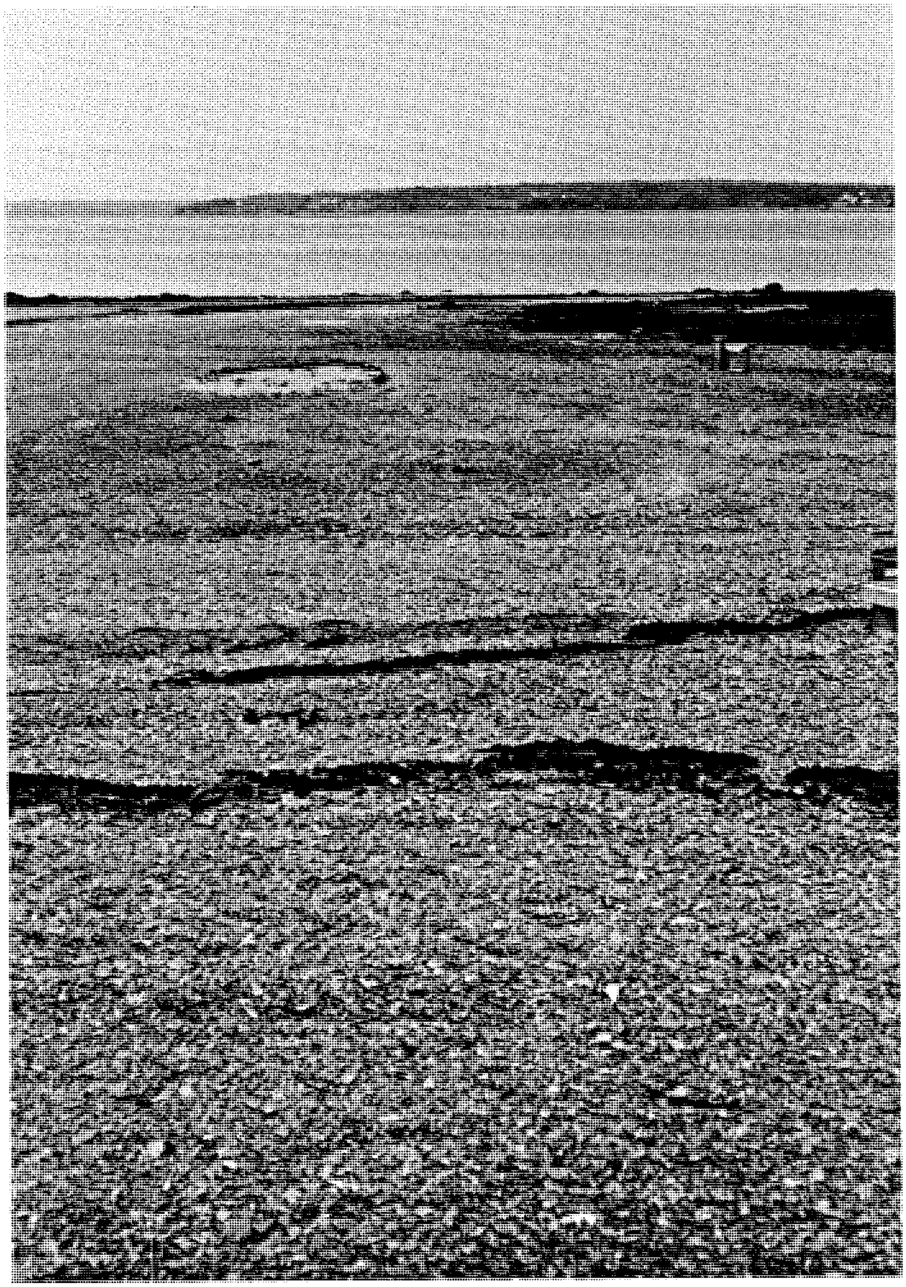

Figure 18. A wide gravel beach on Mount Desert Island.

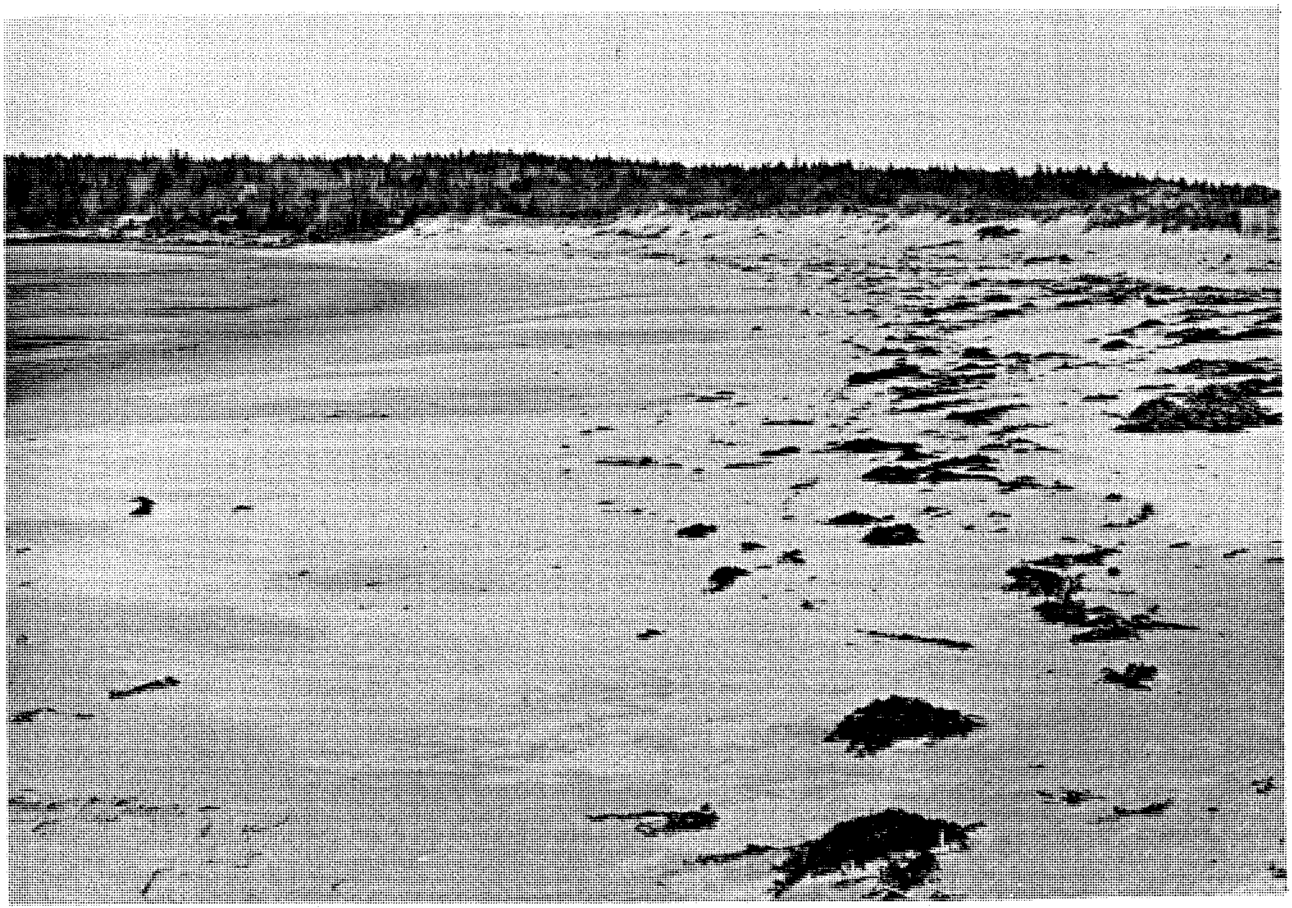

Figure 19. The sand beach at Reid State Park, Georgetown.

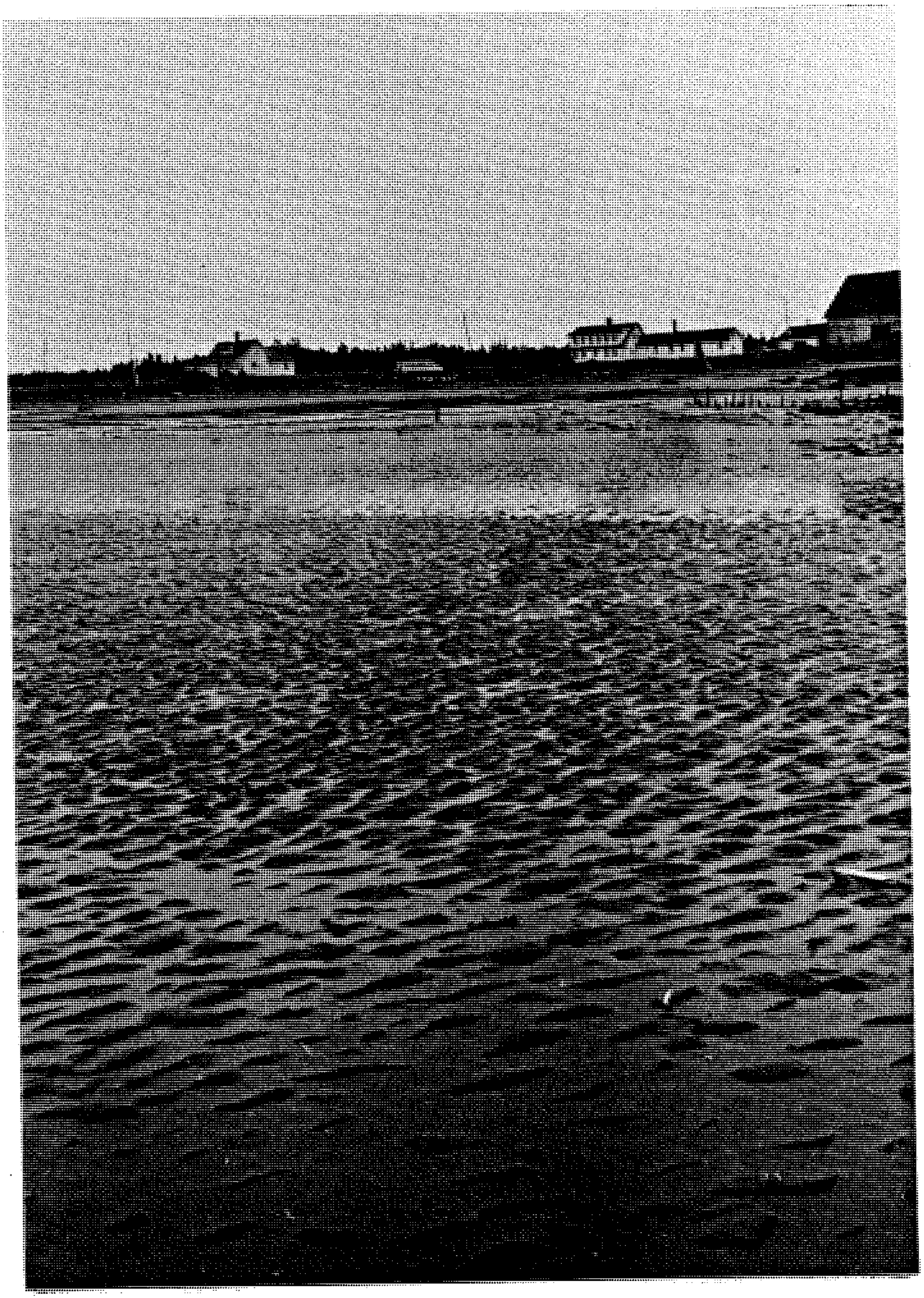

Figure 20. A large sand flat at the head of Bailey's Mistake in Trescott.

Figure 21. Hodgdon Cove mud flat in Boothbay Harbor.

Figure 22. The salt marsh just north of Route 95 on the Cousins River, Yarmouth.

CORRELATIONS TO MGS MAPS

Certain of the geological intertidal environments correlate with the ecologically defined habitats of the current study. These similarities are as follows: our high and low energy rocky shores are called ledges on the MGS maps; ecologically defined boulder beaches are listed as boulder beaches, boulder ramps, and gravel beaches on the MGS maps; our cobble beaches fall within the MGS definition of gravel beaches; MGS calls our gravel beaches both mixed sand and gravel beaches and low-energy beaches; our sand beaches include both sand beaches and spits in the MGS classification; our sand flats are classified as coarse-grained flats and point or lateral bars; our mud flats include MGS's mud flats, and probably also algal flats and mussel bars; our salt marsh includes all of MGS's salt marsh environments.

There is usually overlap of several MGS environments with any one of our own. This is because MGS separated environments based on their geological structure or formation, which may or may not be of ecological significance. In the faunal program, we chose to define the habitats from an organismic point of view, i.e. any environment to which an organism responds as being a sandy beach, we called a sandy beach, whether it was a beach or a spit. Conversely, whereas MGS calls all intertidal bedrock ledge, we must differentiate between low and high-energy rocky shores because the fauna, flora and pattern of zonation is different between the two.

One final word of caution - air photo interpretation, or any remote sensing method, is problematical on a detailed scale or in differentiating between habitats that appear similar on the imagery. On this scale, there are normally some errors in interpretation.

SELECTION OF SAMPLING SITES

Representatives of each habitat were chosen along the entire coast of Maine on the basis of our own experience and interviews with knowledgeable persons. Attempts were made to find two good, accessible, examples of each habitat between Kittery and Cape Elizabeth, and three of each in the other two zones, even though it was realized that all samples from each habitat could not be worked up. It was not always possible to find enough suitable sites for each habitat that could be reached by truck. For this reason, fewer than eight sites were sampled for sand flats (5), gravel beaches (7), boulder beaches (6), and low-energy rocky shores (6).

Only three salt marshes were sampled because of the great difficulty in processing marsh samples and because less faunal variability was expected. Marshes deserve their own special intensive study.

The locations of the sampling sites are shown in Fig. 23, and the dates on which samples were taken are presented in Appendix I.

THE SAMPLING PROCESS

At each site chosen for sampling, two transects were laid out across representative areas of the shore. Two transects were deemed necessary to get a rough idea of the heterogeneity of the habitat. Four ¼ m^2 samples were taken along each transect (Fig. 24). Sampling was done as near to spring tides as possible so that the lower part of the intertidal zone would be exposed. Sampling points were located at the low tide line, at the place of the last high tide line, i.e. at the wrack line, and at two points between that divided the intertidal zone into four vertically equal sections (Fig. 25).

In sedimentary environments, such as sand beaches, sand flats, mud flats, and gravel beaches, the sediment within each ¼ m^2 sampling frame was shovelled into buckets, and the area was cleaned out to a depth of at least 15 cm (most organisms occur in the top 5 cm of sediment) (Fig. 26). The area within the frame was then dug out deeper to inspect for any large, deep burrowing animals such as sand worms, razor clams, or soft clams (Fig. 27). The diggings, usually four buckets per sample, were then returned to the laboratory or field station for processing (Fig. 28).

At cobble beaches the larger rocks were checked in the field for attached epifauna. Only those rocks with animals on them or on the underlying sediment were removed from the site.

Rocky shores and boulder beaches required a slightly different approach, since little sediment was encountered. On rocky shores the area within the sampling frame was first cleared of macroalgae, which were placed in a plastic bag for later laboratory examination (Fig. 29). All of the remaining material on the rock surface was scraped off with putty knives and put into jars. Crevices within the sampling area were cleaned out using spatulas and forceps. At the two stations below mean tidal level, this meant removal of all living material from the ¼ m^2, leaving only bare rock. These areas were quickly recolonized, and one year later the spots sampled could not be differentiated from surrounding areas.

In the barnacle zone, a given subarea within the ¼ m^2 frame was randomly selected and all of the obvious organisms, barnacles, and the tiny periwinkle *Littorina saxitilus*, were counted. Because this zone is very homogeneous, it was not necessary to disturb the whole area. A small patch of

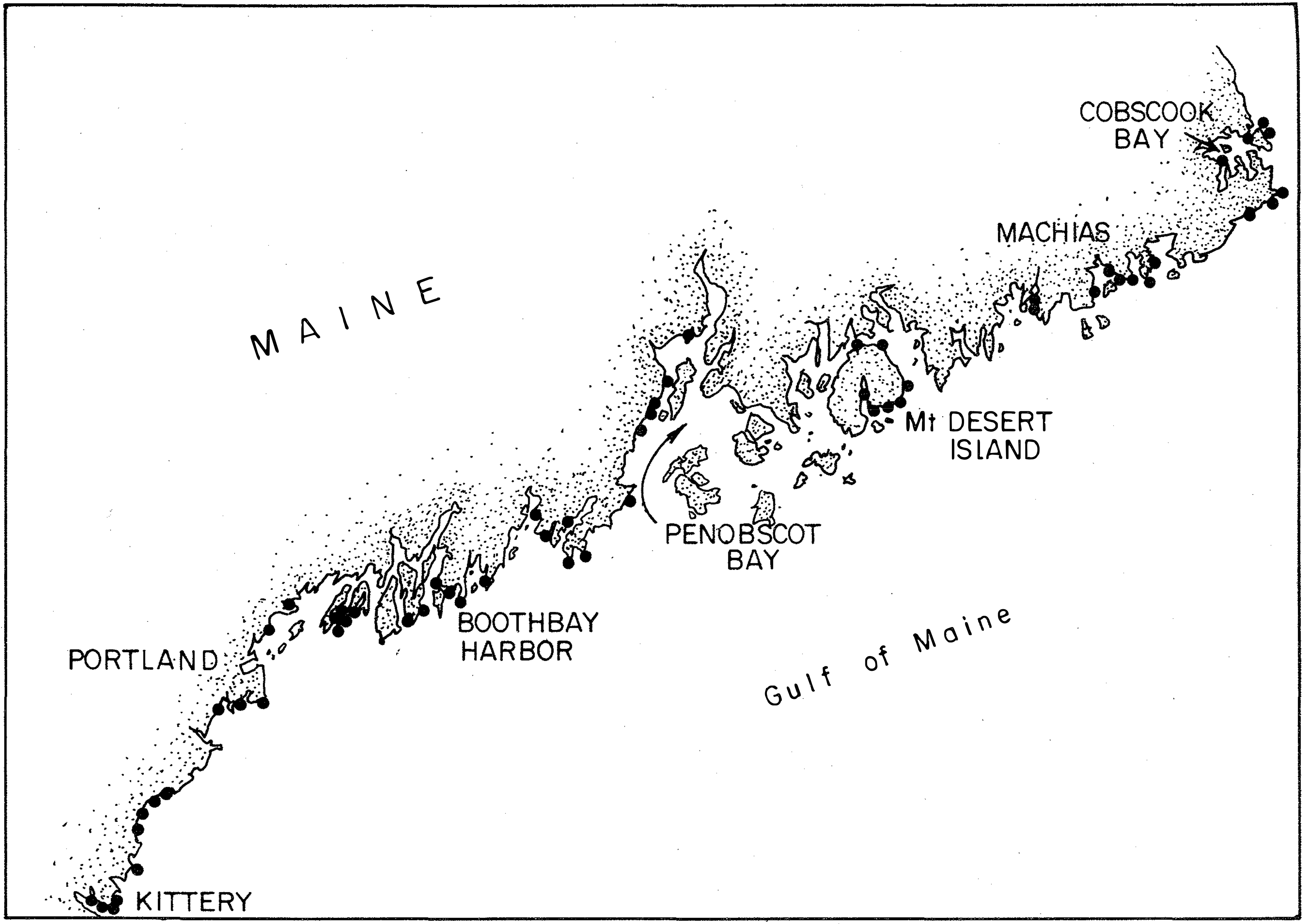

Figure 23. Locations of the 59 intertidal sites sampled during the summers of 1975 and 1976.

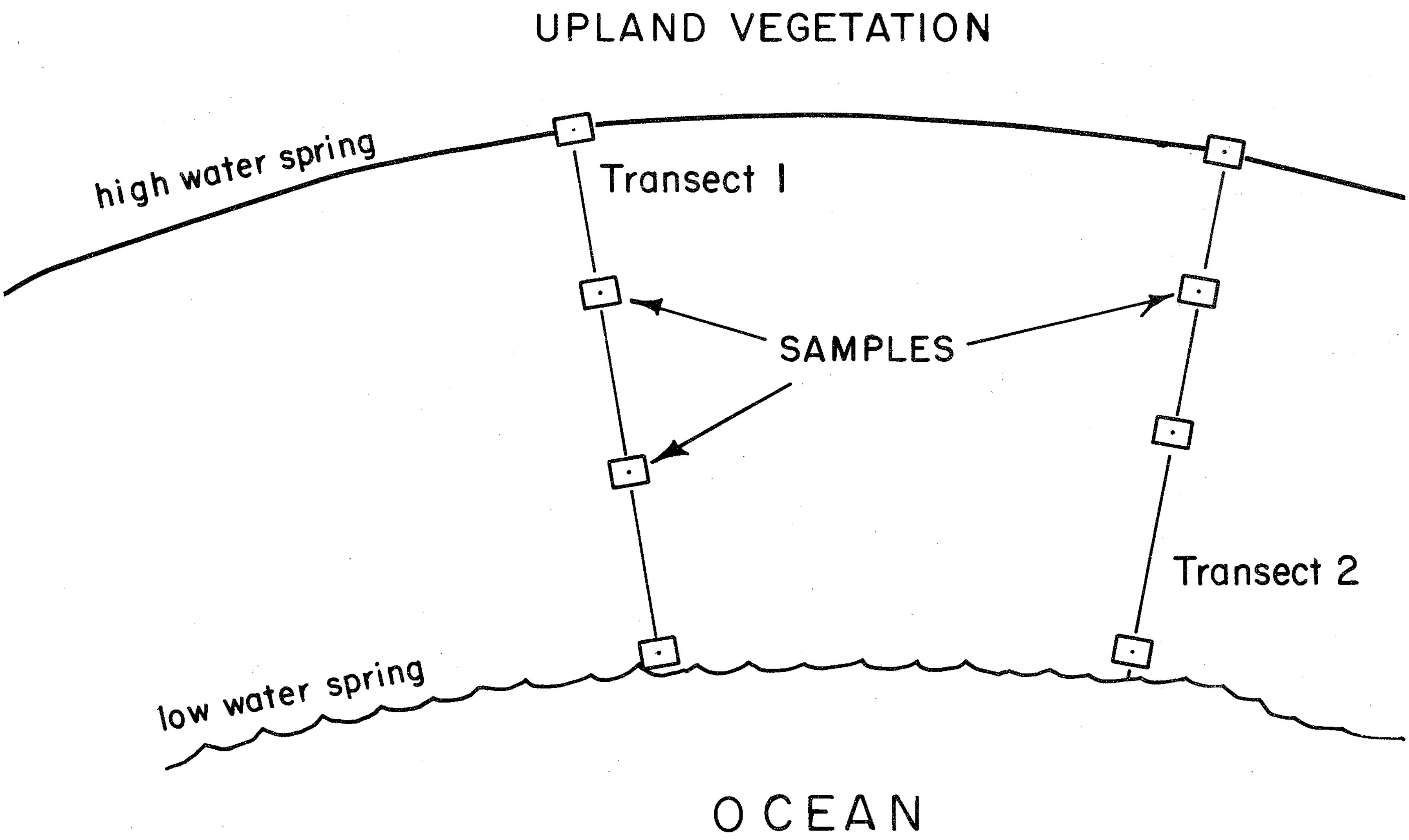

Figure 24. A schematic representation of the sampling design.

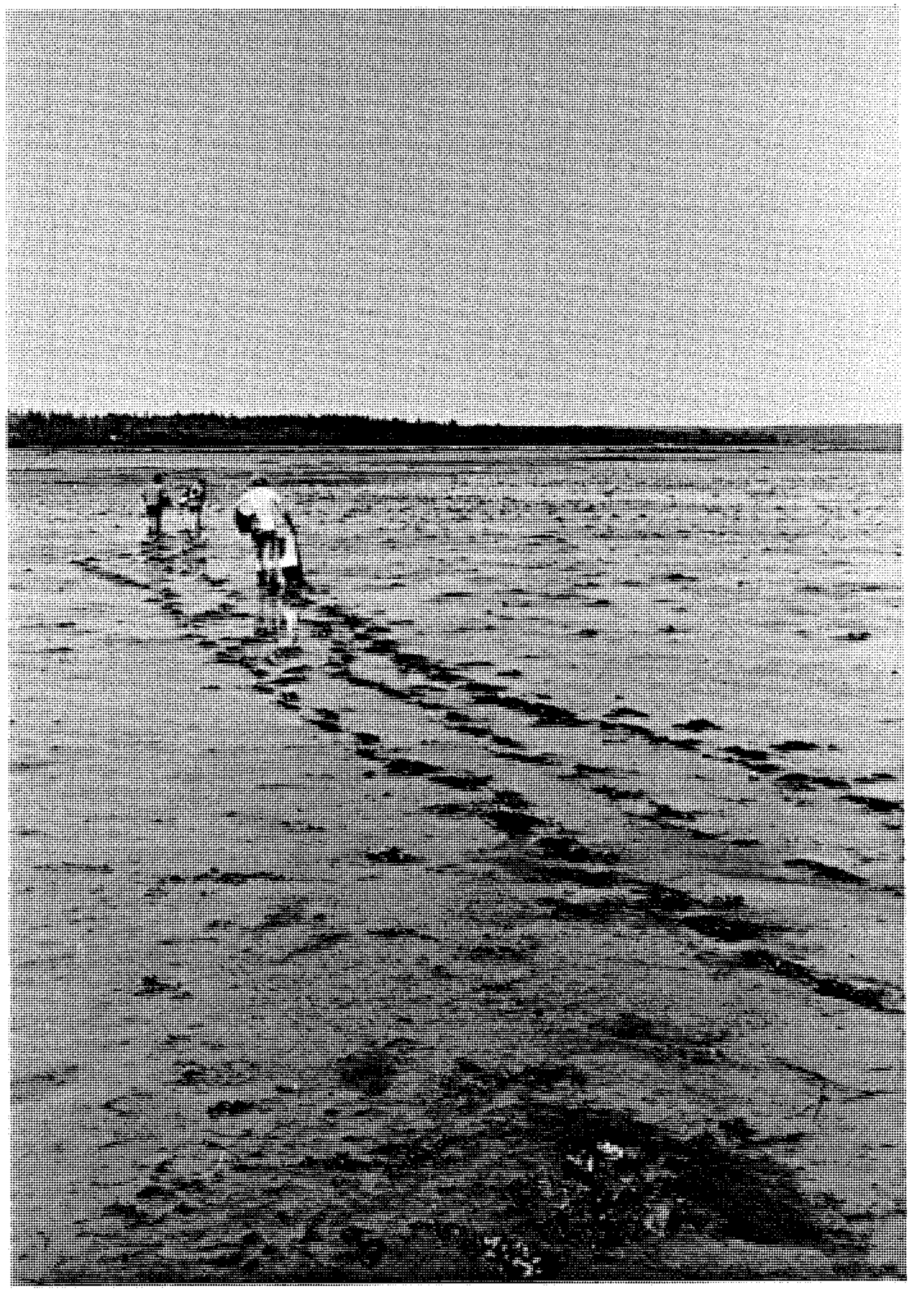

Figure 25. Setting out a mud flat transect at Acadia National Park.

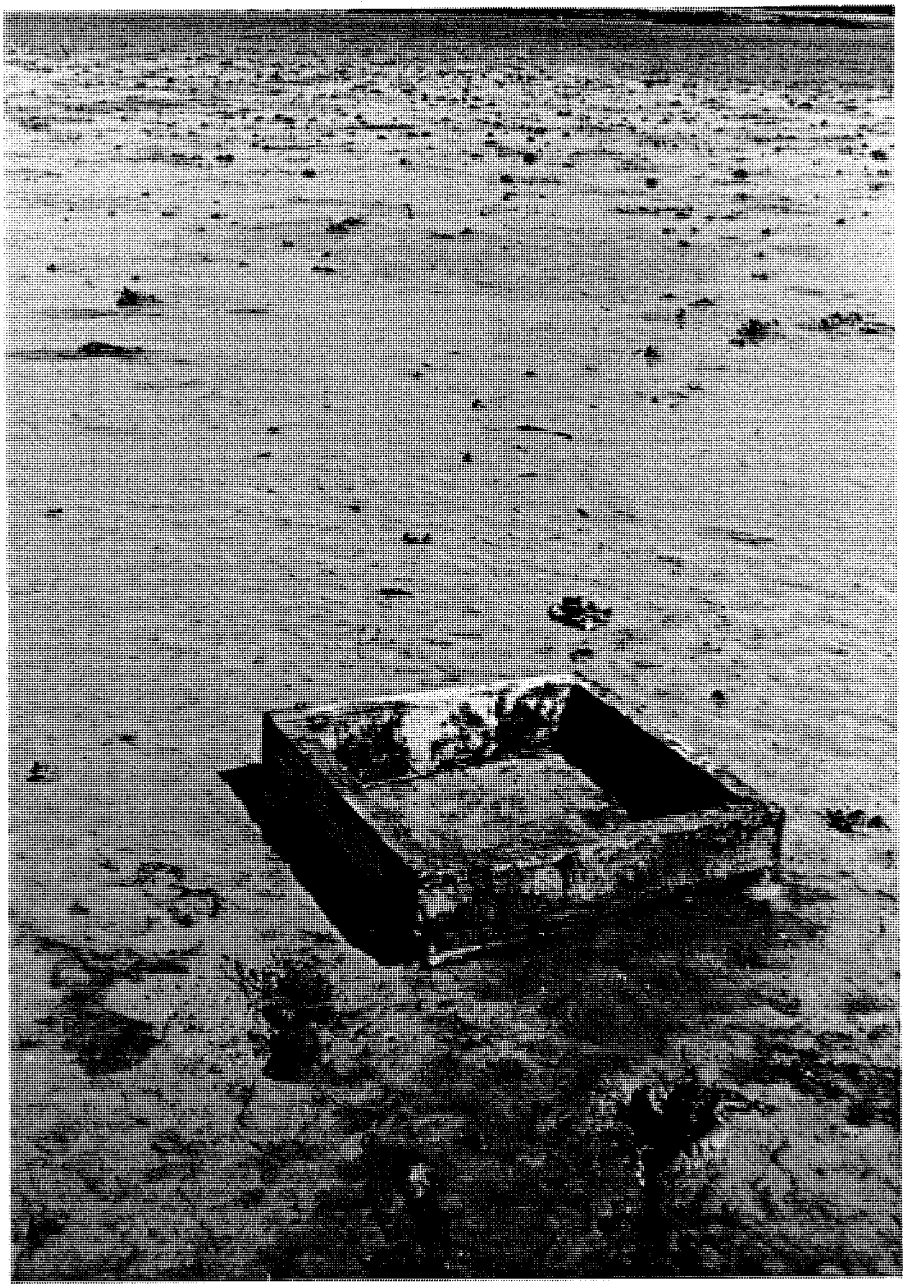

Figure 26. The quarter meter square sampling frame.

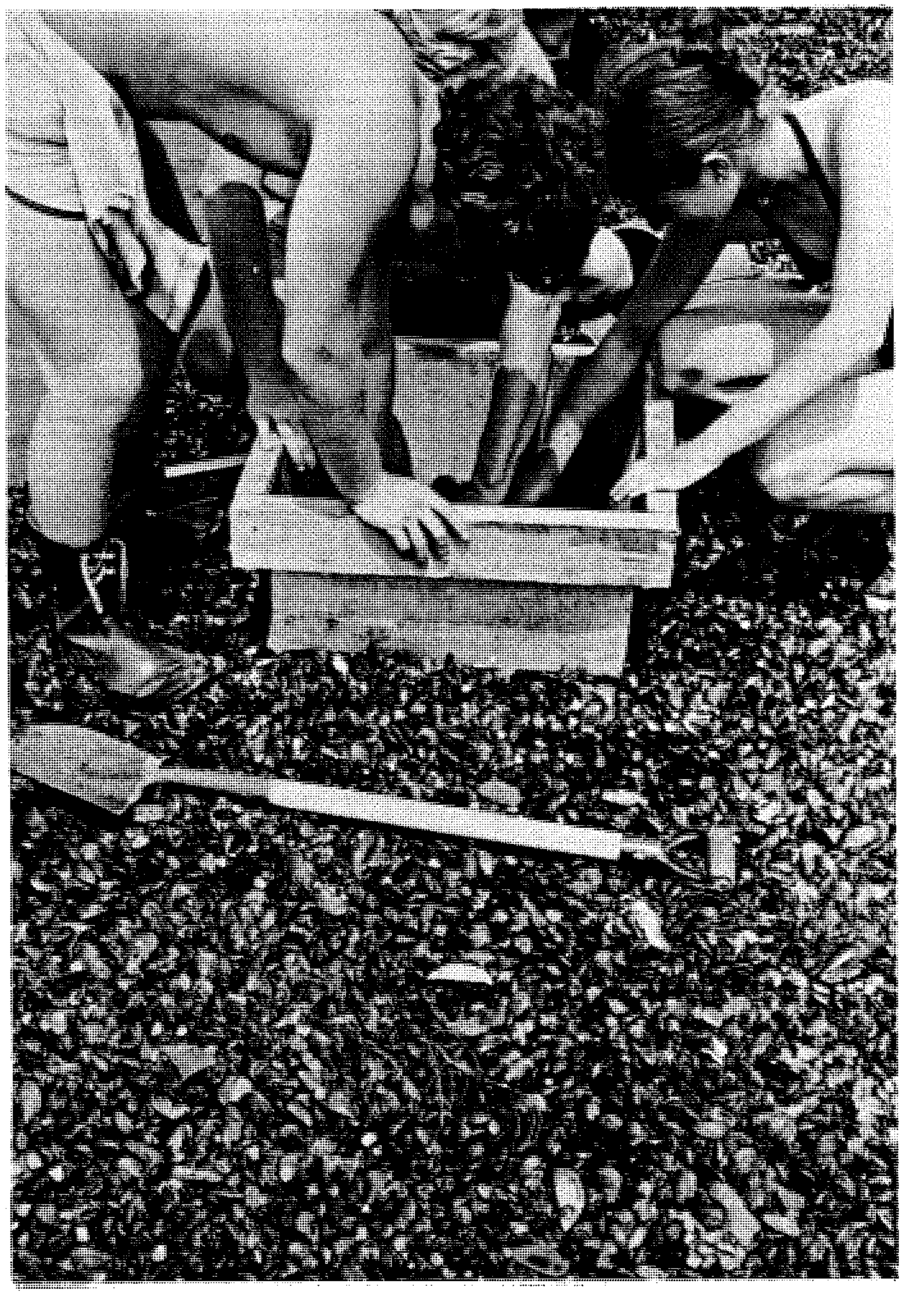

Figure 27. Checking for deep burrowing forms.

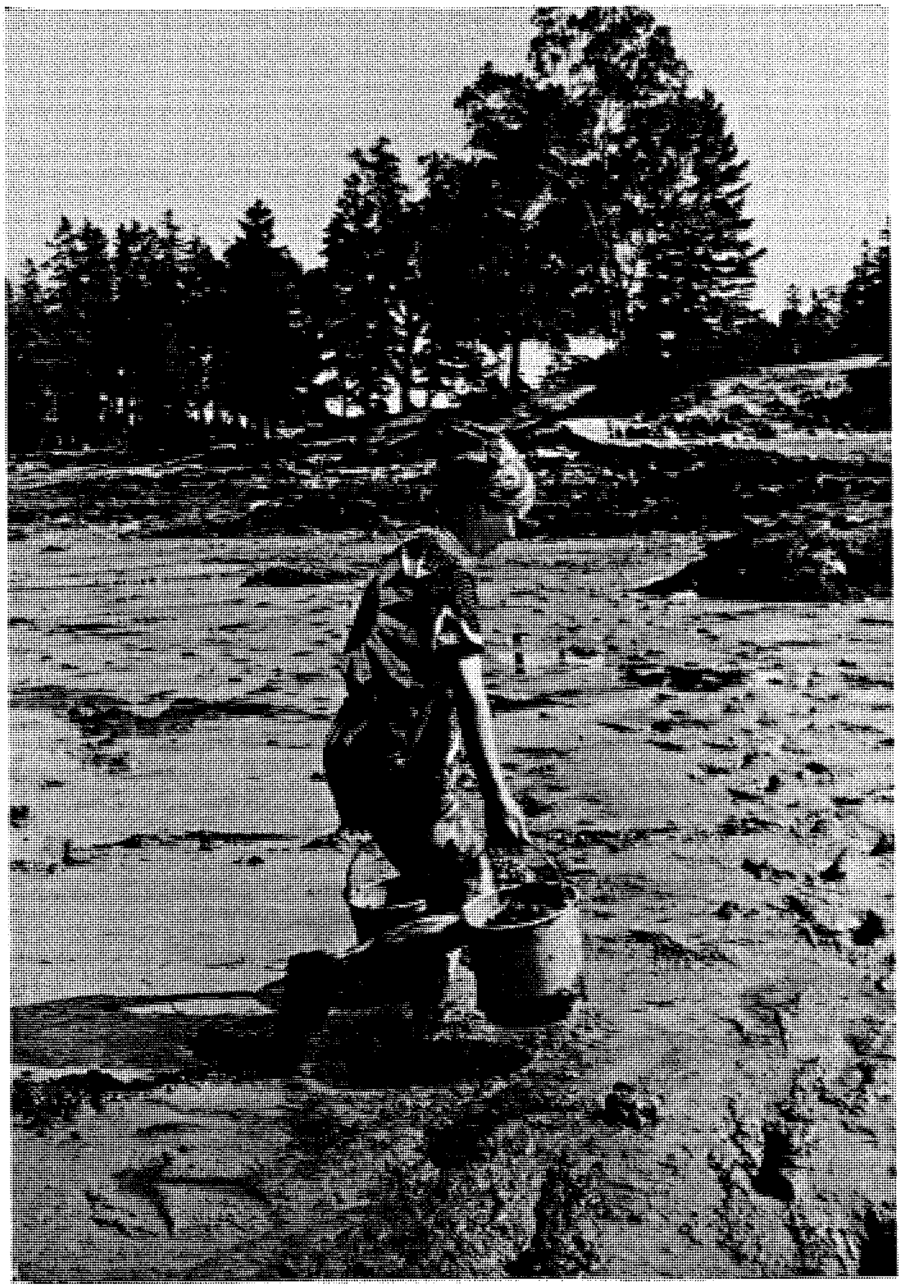

Figure 28. Initial steps toward returning samples to the Mount Desert field station.

barnacles was removed, however, to examine in the laboratory for oligochaetes and nematodes which are not easily seen in the field.

Very few individuals live at the highest intertidal levels, so these organisms were identified and counted in the field.

Boulder beaches were treated similarly to rocky shores with the exception that the sediment between and under the boulders was collected and returned to the lab for microscopic investigation.

At a small number of the sites, the habitat of interest was not continuous to the upper intertidal zone. At these sites the transects were limited to three samples each.

Salt marshes are truly unique environments, and therefore require different sampling techniques. Transects of five or more stations were established. Stations were located in the upper and lower *Spartina patens* zone, the upper and lower *Spartina alterniflora* zone, the marsh bank, and the edge of the marsh creek. Each blade of grass within the ¼ m^2 frame was examined for fauna, as was the marsh surface. From within the frame a 1/16 m^2 sample of the substrate was taken. This was essentially a lump of grass roots. The bank and creek samples were also 1/16 m^2 in area.

At every station extensive field notes were taken (Fig. 30). Included was a photograph of each point to be sampled and several general photos of the site. Temperatures were taken at the sediment surface, at the bottom of the hole resulting from the sampling process, and in the water. Salinity samples were taken where possible and, at most sites, sediment samples were taken, although funding has not been available to work them up.

After this process was completed, each site was qualitatively searched for species which may have been missed in the systematic sampling.

SAMPLE TREATMENT AND LABORATORY PROCESSING

When the samples were returned to the laboratory or field station, they were treated in the following way. Sediment samples were sieved on a 1.0 mm mesh screen. This process removed all of the sediment particles and debris of less than 1.0 mm diameter, which greatly sped up the pre-sorting process.

All samples were fixed in a 10% formalin solution to which the vital stain rose bengal had been added. Rose bengal stains living animal protein pink, which makes the animals stand out from the inorganic sediments. Before pre-sorting the samples were rinsed with tap water and preserved in a 70% solution of ethanol.

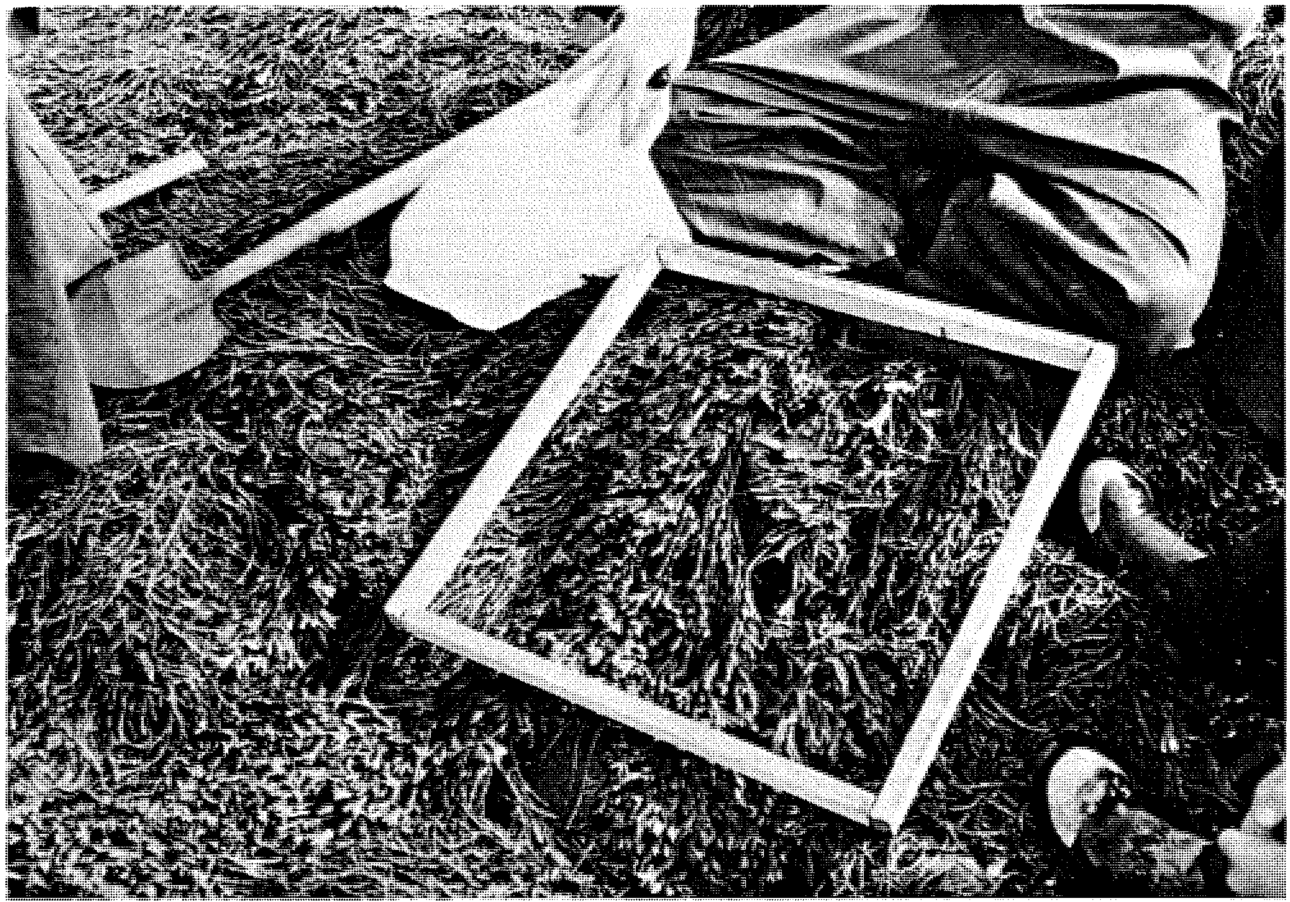

Figure 29. Sampling frame used on rocky shores.

Figure 30. Recording of observations and measurements made in the field.

The pre-sorting process involved the removal of the organisms from the remaining sediment and debris and sorting them to major taxonomic categories such as molluscs, polychaetes, and crustaceans. Much of this tedious work was done with the aid of a low-power dissecting microscope (Fig. 31).

During the final sorting process, each individual organism was identified to the species level or the lowest taxonomic level possible. All of this work was done with a microscope. The individuals of each species were counted and tabulated. Problem species which could not be easily identified were saved or sent to taxonomic experts for identification.

This laboratory processing is the most time-consuming phase of a project of this type and is therefore the limiting factor in how many samples can be processed. It usually takes 40 hours of laboratory time for each hour of collecting time spent in the field. At the present time, sample processing is not complete on samples from 12 of the 59 sites investigated. (See appendix.)

DATA ANALYSIS

The numerical output from the laboratory processing has been analyzed by several techniques. Much of this work has been done on the Digital PDP11 computer at the Bigelow Laboratory for Ocean Sciences, where the data are stored.

Analyses include the ranking of species by their abundance in each sample, the calculation of each species' percentage composition in each sample, and cumulative percentage, densities, etc. Colonial species were not included in the quantitative analyses because of the difficulty in defining an individual. The distribution of each species along the coast has been mapped and frequencies tabulated by habitat and intertidal height.

Shannon's formula for information diversity was used as a measure of the degree of organization in the assemblages of organisms collected. (Shannon's formula (Pielou, 1966) is calculated as $H' = - p_i \log_2 p_i$, where p_i is the proportion of the ith species in the collection.) In its simplest form diversity is the number of species in a sample. This measure, however, does not give any indication of how the individuals are distributed among the species. Two samples may each have 10 species and 100 individuals, but may be organized completely differently. A more sophisticated parameter than species number is required to differentiate between these organizational differences, and Shannon's formula is the parameter most often used. In the above example, for instance, this formula assigns a low diversity value to a sample with 91 individuals in one species and one in each of the nine others. Conversely, it gives a high value to a sample where there are 10 individuals in each of the 10

Figure 31. Removing the preserved animals from the samples in the lab.

species. In other words, the formula takes into account the evenness of the individuals' distribution among the species, as well as the total number of species.

In determining the most important species in a group of stations, a simple rank analysis (as used in ranking the top 20 football teams) is used to reduce the influence in abundance rankings of species which occur in moderate numbers at a large number of stations. By using a rank analysis, often called a bioindex, elements of both abundance and frequency of occurrence can be incorporated into one measure. The five-point system as used here assigns five points to the most abundant species at a given station, four points to the next most abundant, and so on to the fifth most abundant. When the scores of the 5 most abundant species (from each station) are added from all stations, the ranking which is produced is corrected for species that populate limited areas densely.

More sophisticated computer work is now being undertaken to look objectively at intersample, intersite, and, possibly interhabitat relationships. These results will be reported in the scientific literature as they become available.

CHAPTER 6

RESULTS OF FAUNAL STUDIES

A remarkable number of species was collected in the present study (Appendix 2), amounting to 34.4% of the total number of species reported in "A Preliminary Checklist of the Marine and Estuarine Invertebrates of Maine" (Perkins and Larsen, 1975). Some of the species which were found had not been specifically reported before in Maine.

There are many types of habitats found on the Maine coast. Nine distinct types were sampled in this study. There are also numerous habitat combinations present, for instance, gravel-cobble or gravel-high intertidal with sand flat-low intertidal. It is mainly because of the high habitat diversity that so many species are present in Maine's intertidal zone.

The number of individuals of a particular species which is present at a single location varies seasonally (Fig. 32) and also annually. It is very important to know the seasonal and annual abundances of species in order to be able to predict accurately the potential impact of environmental stress (natural or man-induced). Although sampling occurred only once at each location in the present study, we were able to establish what and how many animals were present in early-mid summer, when theoretically species are at their peak abundance. For example, numerous juvenile mussels (*Mytilus edulis*, the blue mussel) were present in our samples. If the same areas had been sampled later in the season, fewer, but larger, mussels would have been found, since the less hardy ones die in the competition for food and space or by being devoured by predators.

Many animals found in the intertidal zone are ubiquitous. This means that they are able to live and are found in a variety of habitats and tidal heights and have a wide geographic distribution. They also tend to be more resistant to stress (both man-induced and natural) than other marine animals. Because they are able to establish themselves in a variety of habitats, localized habitat destruction has little effect on their total populations. The following taxa were found at all tidal heights, in all habitats, and were distributed along the entire coast of Maine:

Nematoda	
Nemertea	
Oligochaetes	same group as earthworm
Nereis virens	sand worm (polychaete)
Eteone longa	polychaete worm
Polydora sp.	polychaete worm
Littorina littorea	common periwinkle
Littorina obtusata	smooth periwinkle
Mytilus edulis	blue mussel

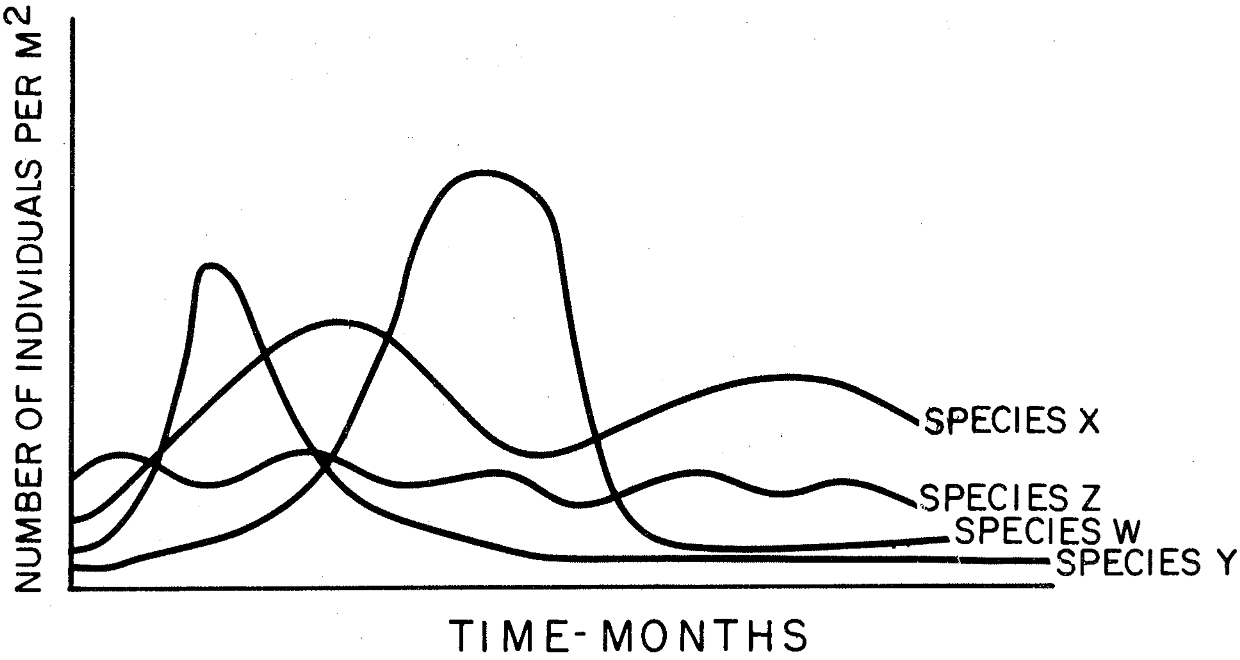

Figure 32. Hypothetical species abundance curves over a seasonal cycle.

Mya arenaria	soft shelled clam
Balanus balanoides	barnacle
Jaera	isopod (looks like sowbug)
Gammarus oceanicus	amphipod (scud)
Carcinus maenas	green crab

Of particular interest are the oligochaetes, which besides being found at every location and every tidal height, are frequently the most abundant taxon present. The bioindex tables from each habitat (Tables 3, 4, 5, 6, 7, 8, 9, 10, 11) reflects this dominance. Only high and low-energy rocky shores do not have oligochaetes as first on the list, although they are second on the low-energy rocky shore list. If more samples had been worked up for high-energy rocky shores, the oligochaetes would undoubtedly have a higher bioindex score. Unfortunately, oligochaetes are difficult to speciate since most of the specimens are from the family Enchytraeidae, which is poorly known. They have been separated into groups, however, and are being examined by experts in Germany and Sweden.

It is also interesting to note that various arthropods, including insects, were found at a variety of tidal heights and habitats. The groups (which have been saved for more complete identifications later) include the following: larval, pupal, and adult stages of dipterans (midges); arachnids (spiders, pseudoscorpions, mites); ants; millipedes; earwigs; trichopterans (caddis flies); and unidentified insects.

Arrangement of materials and major discussions in this chapter are centered around each habitat and then followed by a section of general comparative comments. A large number of tables is included in this chapter in order to present the necessary data without burdening the narrative with detail too specific for the general reader.

SAND BEACHES

The coast of Maine south of Cape Elizabeth is characterized by long stretches of sand beach separated by rocky promontories. In the north, the number of sand beaches is greatly reduced. Reid State Park, Popham Beach, Pemaquid Beach, and the beaches at and near Roque Island are the only major beaches present along the long coast (over 3,000 miles) north of Cape Elizabeth. There are pocket beaches present (for example at Lincolnville and on Mount Desert Island), but these are few and far between.

The sand of Maine beaches varies from the well-sorted, medium-sized sand grains of Reid to the fine sand of Pemaquid, or the "sand" composed mainly of broken sea urchin spines and shells at Mount Desert. Although sandy beaches generally have a high degree of exposure to the battering of waves, there are varying degrees of absolute exposure depending upon which direction the beach is facing and how much protection is offered by islands or other local topography.

There were a total of 59 taxa found in the present study (Appendix 3, Section 1) at sand beaches. With the exception of salt marshes (which were not studied as completely), this is the lowest number of taxa found at a habitat type. Most of these species were found only at one or two sites. The only taxon which was present at all sites was the ubiquitous oligochaetes. The mean diversity, the mean number of species per station, and the mean number of individuals per square meter are lower than at any other habitat (Tables 1 and 2). The sparsity of species and numbers is due to the fact that a sand beach is a harsh environment in which to live. The sand grains are continually shifting, which means an animal must reestablish its "home" frequently. There is also no substrate present which is suitable for the attachment of animals or plants.

However, there are some species which have adapted to this disruptive type of life, notably the haustorid amphipods, which quickly burrow back into the sand upon being disturbed. The haustorid amphipod *Amphiporeia virginiana* was found only on sand beaches south of the Penobscot River (Fig. 33 and 34) and reached abundance of 24,152 per square meter at the low intertidal mark. Another amphipod, *Talorchestia megalophthalma*, was also found only on sand beaches, but the distribution is statewide (Fig. 35). The bioindex reflects the predominance of haustorids, with three out of the top seven species being haustorids (Table 3).

The high standard deviations present in Table 2 are a reflection of the patchiness of animal distributions, which is the normal condition in field samples. In other words, animals tend to occur in clumps; if a sample is taken in a clump, a very high abundance of animals is found, and if the sample is taken between clumps, a low density is encountered. The resulting wide range of densities produces a large standard deviation, the size of which, relative to the mean, can be used by the investigator to make pronouncements on the nature of the environment.

Two haustorids, *Haustorius canadensis* and *Acanthohaustorius millsi*, occurred on both sand flats and sand beaches. Apparently these animals are not as specialized as the other two amphipods and are able to compete for food, space, etc., in the less stressful environment of a sand flat. The amphipod *Psammonyx nobilis* is also present on both sand beaches and sand flats.

Because there are low numbers of individuals present on sand beaches, the direct or indirect commercial importance is of low significance. However, shore birds do prey upon *Amphiporeia virginiana* (Croker, 1972). Also, storms wash

Table 1. The mean, standard deviation and range of diversity by habitat.

Habitat	No. of Sites	Mean Diversity	Std. Dev.	Range
Mud Flat	5	2.33	± 0.57	1.43 - 3.78
Sand Flat	5	1.82	± 0.83	0 - 3.25
Sand Beach	8	0.90	± 0.75	0 - 3.05
Gravel Beach	7	1.21	± 0.64	.04 - 2.85
Cobble Beach	8	1.28	± 0.73	0 - 2.88
Boulder Beach	6	1.77	± 0.82	.19 - 3.94
Low Energy Rocky	6	1.35	± 0.97	0 - 3.03
Salt Marsh	1	1.40	± 0.68	.37 - 2.20
High Energy Rocky	1	1.52	± 0.76	.34 - 2.37

TABLE 2.

Number of Species and Individuals per meter squared by Habitat

		NUMBER OF SPECIES PER STATION			INDIVIDUALS PER M^2		
Habitat	No. Site	Mean	Std. Dev.	Range	Mean	Std. Dev.	Range
Mud Flat	5	17.4	$\pm$ 5.4	6 - 30	7345.0	$\pm$ 11412.4	624 - 52392
Sand Flat	5	11.0	$\pm$ 5.5	0 - 21	1510.2	$\pm$ 2747.3	0 - 16840
Sand Beach	8	3.9	$\pm$ 2.7	0 - 17	1222.4	$\pm$ 4102.0	0 - 24160
Gravel Beach	7	9.6	$\pm$ 4.8	3 - 25	6457.2	$\pm$ 9795.9	12 - 55804
Cobble Beach	8	9.6	$\pm$ 5.7	0 - 36	9531.6	$\pm$ 19781.9	0 - 11439
Boulder Beach	6	19.4	$\pm$13.9	3 - 72	14693.2	$\pm$ 18314.5	236 - 71752
Low-Energy Rocky	6	13.4	$\pm$ 8.1	1 - 32	10925.0	$\pm$ 12878.0	96 - 48024
Salt Marsh	1	10.5	$\pm$ 4.3	5 - 18	13965.3	$\pm$ 14844.1	352 - 38112
High-Energy Rocky	1	21.0	$\pm$19.8	2 - 55	54896.0	$\pm$ 58523.9	64 - 16868

+ = colonies of hydroids, etc.

Table 3. Bioindex values summated for all 8 sand beach sites.

Organism	Total	Frequency
Oligochaeta	113.00	8
Amphiporeia virginiana	83.50	4
Nematoda	49.50	7
Haustorius canadensis	37.00	3
Acanthohaustorius millsi	36.00	2
Psammonyx nobilis	35.50	4
Talorchestia megalophthalma	32.00	4
Mytilus edulis	28.95	9
Nephtys caeca	27.75	3
Paraonis fulgens	25.70	3
Ophelia sp.	24.50	1
Scoloplos	21.50	1
Scolepis squamata	19.50	3
Insecta - larva	19.25	2
Insecta - adult	17.25	4
Arachnid	13.50	3
Nephtys bucera	12.83	3
Chironomid - larva	11.00	2
Littorina littorea	10.00	3
Mya arenaria	7.75	2
Coleoptera - adult	7.50	2
Glycera dibranchiata	7.00	1
Dipteran - larva	6.50	1
Insecta - pupa	6.50	2
Chiridotea Caeca	6.00	2
Anurida maritima	5.50	2
Odostomia sp.	5.50	2
Nephtys picta	5.00	1
Orchestia platensis	5.00	2
Chaoberus sp.	4.50	1
Littorina obtusata	4.50	1
Carcinus maenus	4.00	1
Spiophanes bombyx	4.00	1
Gammarus oceanicus	3.50	1
Lacuna Vincta	3.25	2
Chiridotea tuftsi	3.20	1
Cirratulus grandis	3.00	1
Skeneopsis planorbis	3.00	1
Ant	2.50	1
Jaera sp.	2.50	1
Polychaeta Unidentified	2.25	2
Nemertea	2.00	1
Mite	2.00	1
Belanus balanoides	1.50	1
Thais lapillus	1.50	1
Eudorella truncatula	1.45	1
Nereis virens	1.20	1
Nassarius trivittatus	0.33	1
Orbinia sp.	0.33	1

HABITAT	FREQUENCY
High-energy Rocky Shore	
Low-energy Rocky Shore	
Mud Flat	
Sand Flat	
Sand Beach	20
Gravel Beach	
Cobble Beach	
Boulder Beach	
Salt Marsh	

TIDE ZONE		FREQUENCY
High	A	3
High-Mid	B	5
Mid	C	
Low-Mid	D	6
Low	E	6

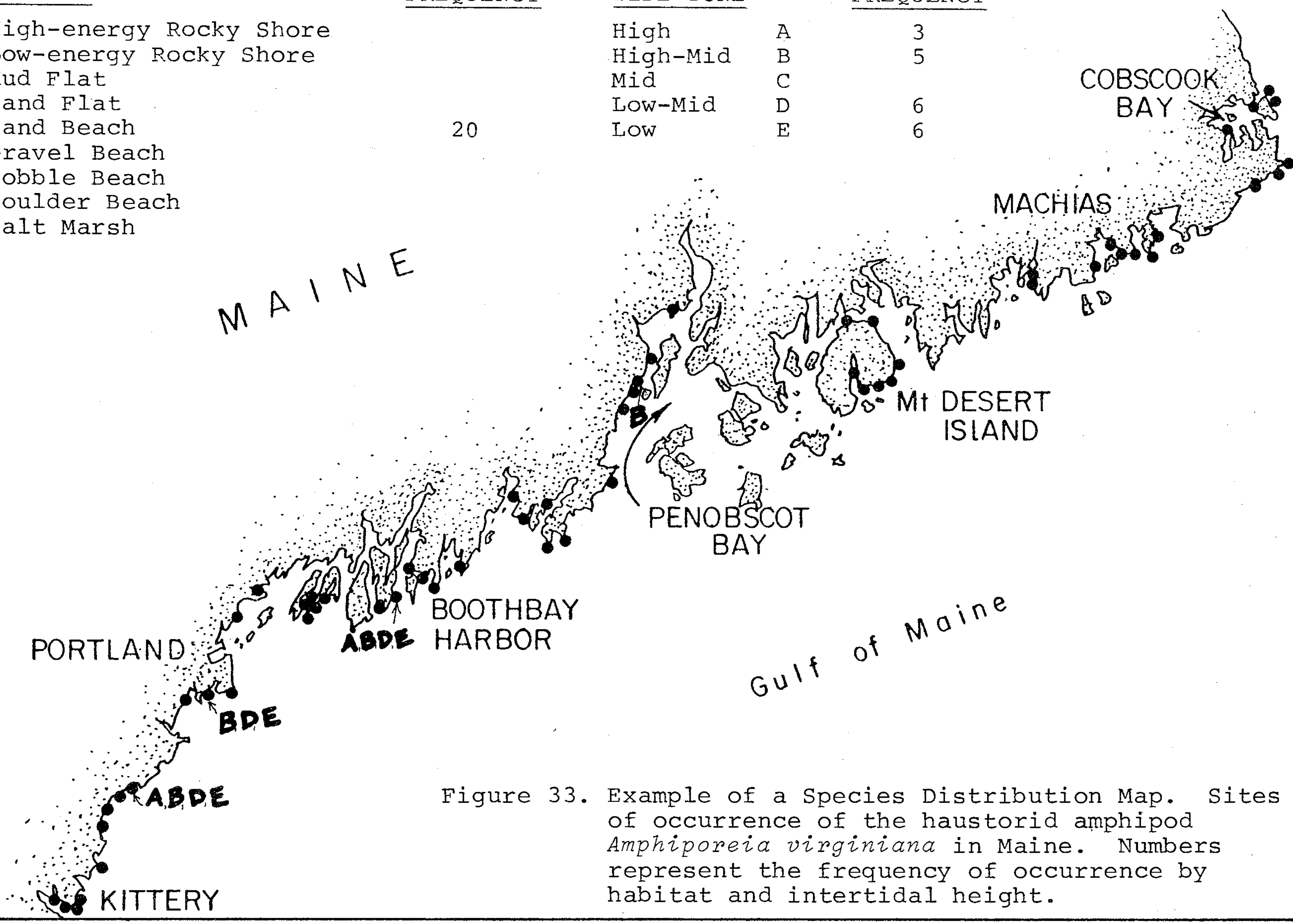

Figure 33. Example of a Species Distribution Map. Sites of occurrence of the haustorid amphipod *Amphiporeia virginiana* in Maine. Numbers represent the frequency of occurrence by habitat and intertidal height.

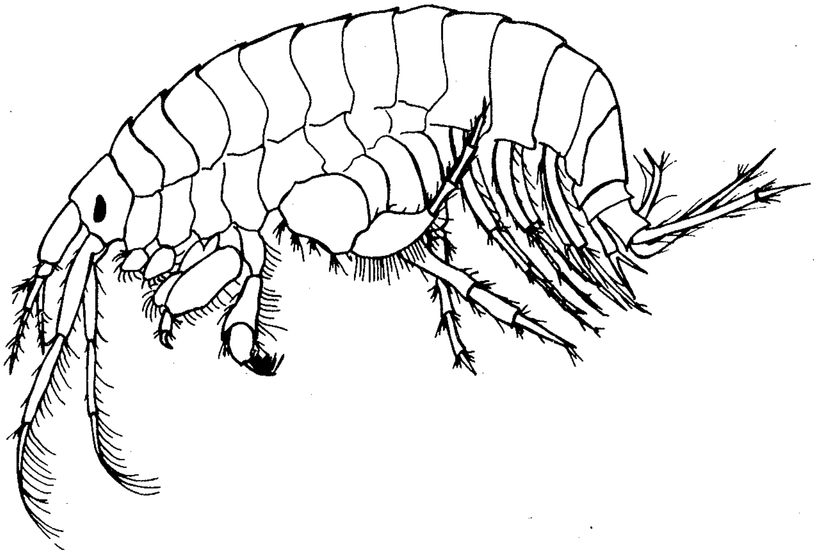

Figure 34. The dominant sand beach amphipod *Amphiporeia virginiana*. Total length is about 4 mm.

HABITAT	FREQUENCY
High-energy Rocky Shore	
Low-energy Rocky Shore	
Mud Flat	
Sand Flat	
Sand Beach	8
Gravel Beach	
Cobble Beach	
Boulder Beach	
Salt Marsh	

TIDE ZONE		FREQUENCY
High	A	7
Migh-Mid	B	
Mid	C	
Low-Mid	D	1
Low	E	

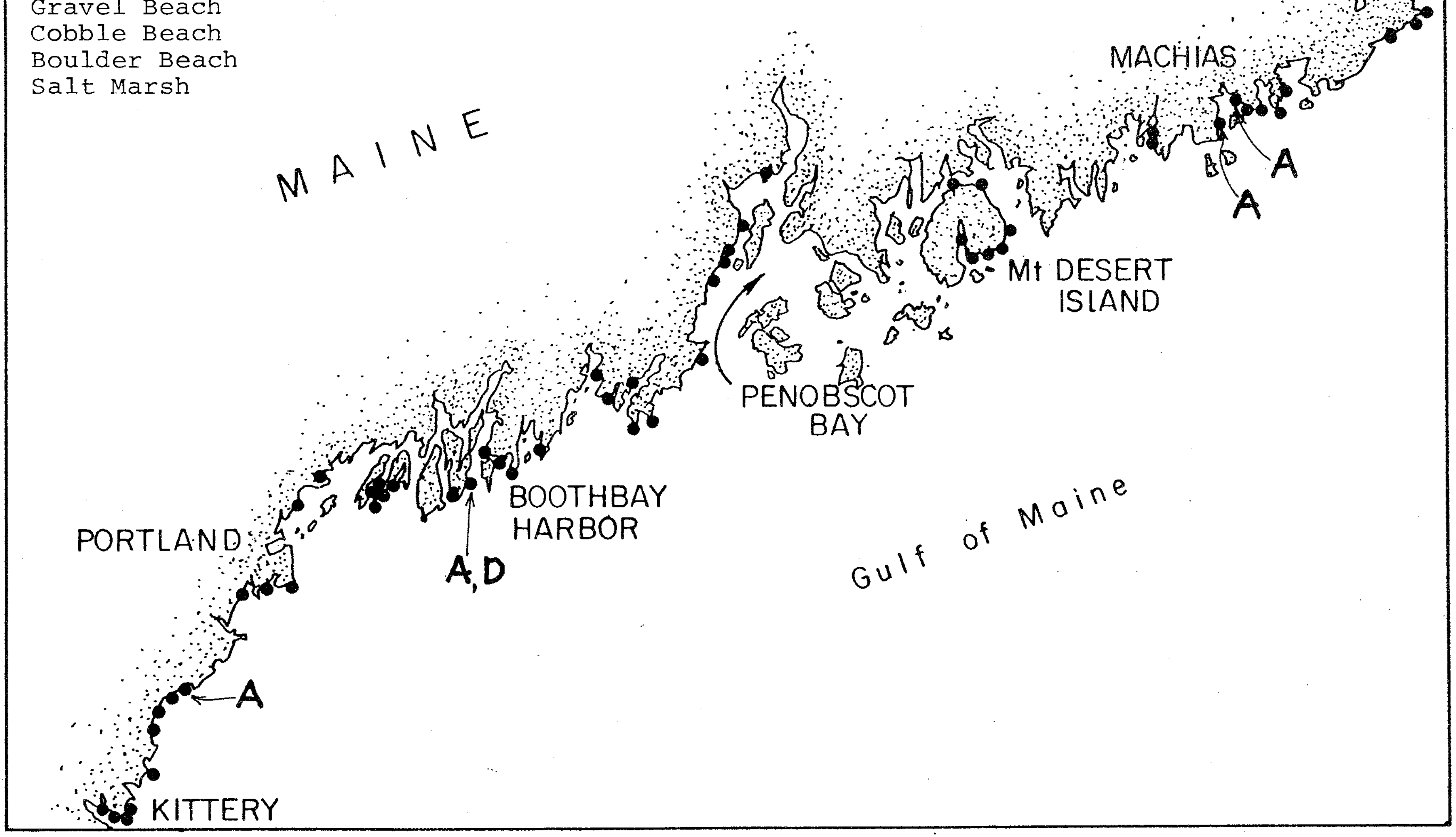

Figure 35. The distribution of the amphipod *Talorchestia megalophthalma* along the coast of Maine.

Spisula solidissima, the surf clam, to the immediate subtidal area of Maine's southern beaches, where it is harvested.

Although major erosional activity, construction activities (such as covering an area with mud), and the effects of oil or toxic wastes are harmful to the animals of a sand beach, minor perturbations have little effect. Foot traffic and small-scale construction activities such as building sand castles are considered minor perturbations.

SAND FLATS

The number of large sand flats in Maine is rather limited. Along the eastern coast of the United States south of Maine, low-energy intertidal flats are commonly composed of sand. In Maine, however, particularly north of Cape Elizabeth, most of the source material for low-energy systems is silt and clay, which results in the extensive mud flats found along our coast. The major sand flat areas in Maine are the following: Sagadahoc Bay and Heal Eddy, Georgetown; Gerrish Island, Kittery; Bailey's Mistake, Trescott; and Clam Cove, Rockport. These flats can easily be distinguished from a mud flat by the sand waves present on their surfaces (Fig. 36). Other less extensive (in area) sand flats occur behind beaches where small estuaries empty into the ocean. Such is the case at the southern end of Reid State Park behind Wells Beach, Thompson Point Beach, Old Orchard, and behind Ogunquit Beach. Often the upland extent of these sand flats is salt marsh, for example, the Scarborough marsh.

In all, 71 taxa were collected at the sand flats sampled (Appendix 3, Section 2). The number and type of species found reflect the fact that some of the sand flats in Maine may have "pure" sand (Gerrish Island, Kittery and the outer reaches of Heal Eddy, Georgetown) while other parts of the same flats or other flats have some silt and clay mixed with the sand (Glen Cove, Rockport, and the inner part of Heal Eddy). The "pure" sand areas have many amphipods, and the sand-silt-clay areas have a number of species found more typically in mud flats, such as Macoma balthica (the Baltic clam) and various polychaete worms. Only the nematodes, which are hair-like worms found everywhere and in nearly every habitat of the world, were found at all sample sites.

Oligochaetes and nematodes rank first and third, respectively, on the bioindex list (Table 4). The second species, the haustorid amphipod *Acanthohaustorius millsi* ranks fifth on the bioindex table for sand beaches (Table 3). In general, polychaetes have replaced haustorid amphipods, which were the dominant taxon of sand beaches, at the top of the bioindex list for sand flats.

Table 4. Bioindex values summated for all 5 sand flat sites.

Organism	Total	Frequency
Oligochaeta	52.00	4
Acanthohaustorius millsi	42.00	2
Nematoda	39.00	3
Pygospio elegans	37.00	4
Spiophanes bombyx	31.00	2
Nereis virens	30.00	3
Protohaustorius deichmannae	29.00	1
Psammonyx nobilis	29.00	4
Mya arenaria	24.50	2
Exogone hebes	22.50	3
Scolecolepides viridis	20.00	2
Chiridotea coeca	15.00	1
Nephtys coeca	14.50	3
Nemertea	14.00	3
Macoma balthica	13.50	4
Scoloplos sp.	13.00	3
Tellina agilis	12.50	2
Aricidea jeffreysii	11.00	1
Capitella capitata	11.00	1
Gemma gemma	11.00	1
Spio setosa	10.00	1
Haustorius canadensis	9.50	1
Paraonis fulgens	9.50	2
Nereis diversicolor	9.00	2
Clymenella torquata	5.00	1
Heteromastus filiformis	5.00	1
Mytilus edulis	5.00	1
Unknown phylum - Leech?	4.00	1
Chiridotea tuftsi	3.00	1
Corophium volutator	2.00	1
Eteone longa	2.00	1
Gammarus lawrencianus	1.00	1
Leptocuma minor	1.00	1
Spio sp.	1.00	1
Littorina littorea	0.50	1
Nephtys bucera	0.50	1
Saccoglossus kowalevskii	0.50	1

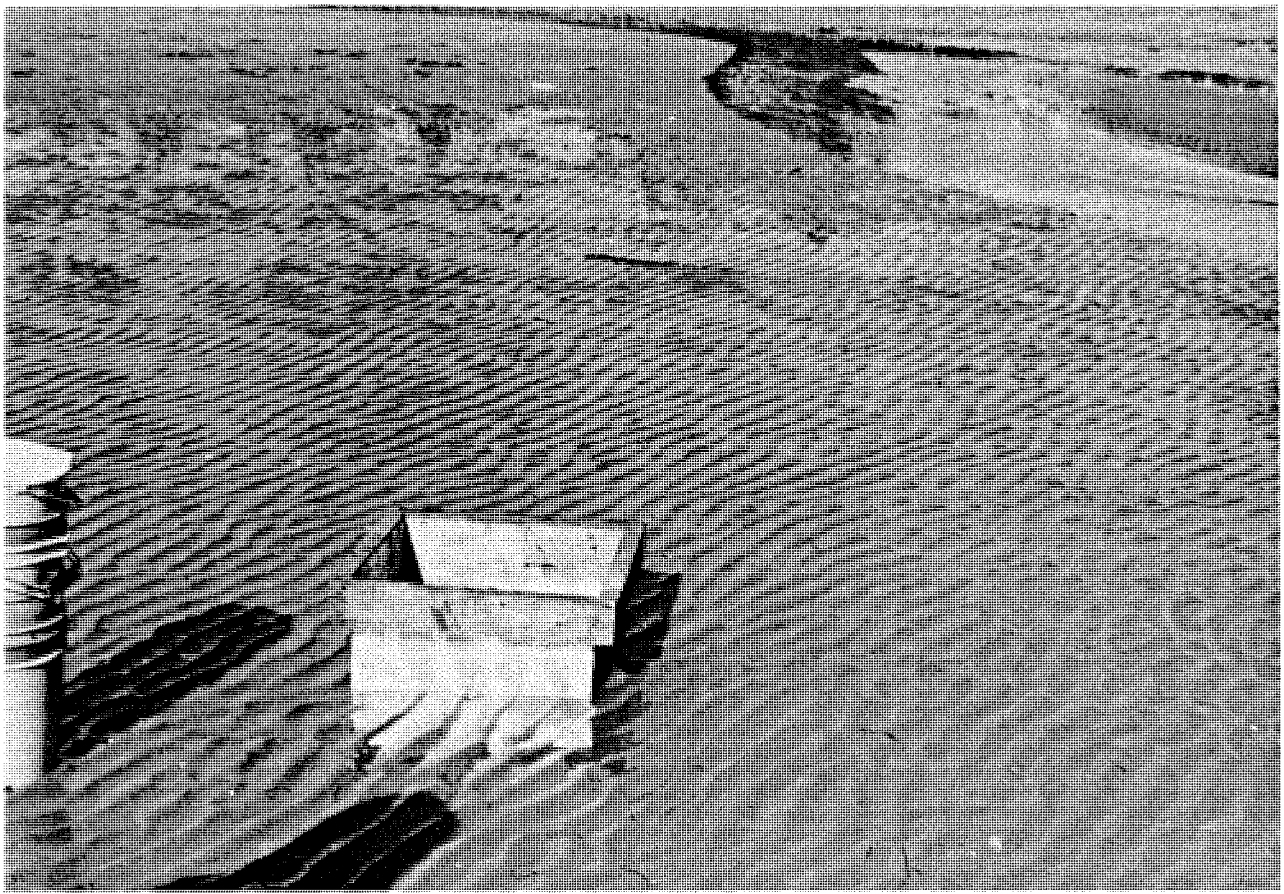

Figure 36. Photograph of the surface of a typical sand flat.

The soft shelled clam, *Mya arenaria*, was present at four out of the five sites sampled and ranked ninth on the bio-index list (Table 4). Many of these flats appeared to have large numbers of large clams present (judging from the siphon holes). Also found on the sand flats at Kittery (where no clams were present in the samples) and Georgetown was the moon snail, *Polinices heros*, a well known predator on clams (Fig. 37).

Diversity on sand flats is second only to the highly diverse mud flats (Table 1). The mean number of individuals per square meter is only 300 per square meter higher than at sand beaches. Sample sites included the Wells sand flat, which has had frequent dredging activities adjacent to it, making the number of individuals per square meter inordinately low. Besides having a very low number of individuals, Wells also had very few species and only one crustacean (the amphipod *Corophium*).

Several species collected on sand flats were found to have a preference for fine sedimentary environments, which also include mud flats and marsh bank areas. The following species were found in these areas exclusively: *Crangon septemspinosa*, sand shrimp (abundant in shallow subtidal creeks of flats or marshes); the tiny gastropods (snails) *Hydrobia* and *Odostomia bisuturalis*; the polychaetes *Streblospio benedicti*, *Tharyx acutus*, *Heteromastus filiformis*; and the isopod *Edotea triloba*.

MUD FLATS

Second only to rocky shores, mud flats are a dominant and characteristic habitat type in Maine. North of Cape Elizabeth most low-energy areas such as protected coves and salt marshes drain to expose mud flats. When one looks at a map of Maine's irregular coast, it is obvious that there are numerous protected areas, which low tide exposes as mud flats. The mid-coast area between Casco Bay and Port Clyde is particularly irregular, and has numerous and extensive mud flats. Because the tidal range Downeast is so great, the mud flats there are also extensive in area.

The mud flat environment is very stable in the sense that animals are not particularly disturbed by the daily movement of waves and tides. Many of the animals are relatively sedentary, often living in their tube houses, and feed mainly on organic material in the mud (deposit feeding); however, some, such as *Mya*, may feed on plant and animal material (phytoplankton or zooplankton) in the water column (suspension feeding). Mud flats have various proportions of silt, clay, sand, and organic material. The animals are distributed according to the type of surrounding environment they "prefer" (not by choice, but by natural selection). This results in patchiness, where great numbers of individuals of a particular species are found at one location, while none may be found at a nearby location on the same mud flat.

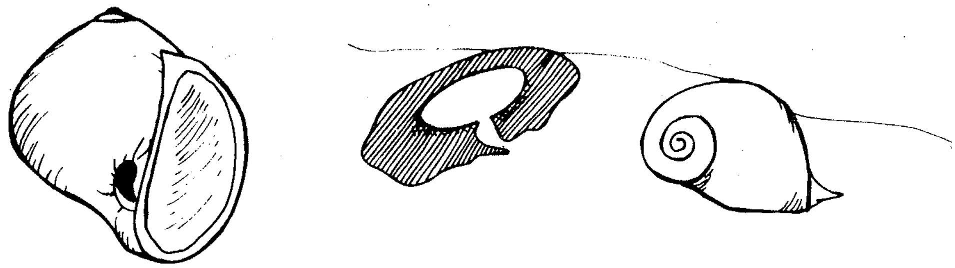

Figure 37. The moon snail *Polinices heros*. Two views of the shell are shown, along with its unique egg collar.

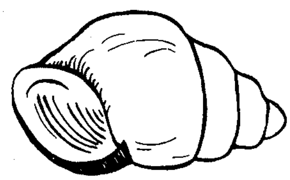

Figure 38. This small snail, *Hydrobia* sp., is very abundant on certain mud flats.

Seventy-five (75) taxa were collected at mud flats in this study (Appendix 3, Section 3). The following ten taxa occurred at all mud flat sites that were completely analyzed: oligochaetes; nematodes; the bivalves *Mya arenaria* (soft shelled clam), *Macoma balthica* (the Baltic clam), and *Mytilus edulis* (the blue mussel); the polychaetes *Nereis virens* (sand worm), *Nephtys caeca*, *Scoloplos* sp. *Streblospio benedicti*, and *Polydora*. There is a high probability that these species are found at any "healthy" (i.e. not perturbed) Maine mud flat. With the exception of *Mytilus edulis*, these species are also found relatively high on the bioindex list (Table 5). Other notable high-ranking species are *Corophium volutator*, an amphipod (Fig. 8), *Gemma gemma*, the gem clam, and *Heteromastus filiformis*, a polychaete.

The mud flat environment has the highest average diversity of the habitats sampled (Table 1). Minor perturbations (such as influx of organic wastes and heated effluent) have the effect of lowering the diversity, since many of the animals are selected against, and the more hardy species (i.e. ubiquitous) are able to thrive. However, major perturbations such as oil can wipe out all species, allowing repopulation by opportunists, as happened with *Capitella capitata*, a polychaete, at Wild Harbor, Massachusetts (Sanders, 1978). Mud flats are the most sensitive of all Maine's habitats to perturbations (natural and man-induced) because the sediments are scarcely flushed. For instance, oil remains in the sediments for years, making the re-establishment of a high-diversity community impossible for a long period of time.

Although lower than for boulder beaches and high-energy rocky shores, the mean number of species per station is relatively high (Table 2). The mean number of individuals per square meter is 7,345; however, at some stations, certain species have very high densities. As many as 24,848 oligochaetes, 23,652 *Gemma gemma* (gem clam), and 16,660 *Hydrobia* (tiny gastropod snail, Fig. 38) per square meter were found at individual station locations.

A number of crustaceans and one gastropod were found only on mud flats in this study. They include the following: amphipods *Gammarus mucronatus*, *Ampelisca abdita*, and *Phoxocephalus holbolli*; cumaceans *Oxyurostylis smithi* and *Leucon nasicoides*; tanaid *Leptochelia rapax* (also found in mud of marsh banks); and gastropod *Nassarius obsoletus* (mud snail).

Mussel bars generally are found on mud flats. The number of mussel bars varies from year to year. Severe storms can wipe out the bars, while warmer water temperatures and appropriate amounts of water movement (not too low, not too high) contribute to bar development. Storms on the Maine coast are often severe and tend to cut back the number of

Table 5. Bioindex values summated for all 5 mud flat sites.

Organism	Total	Frequency
Oligochaeta	119.50	4
Hydrobia	89.00	3
Macoma balthica	57.50	4
Streblospio benedicti	48.50	4
Nereis virens	41.50	4
Corophium volutator	30.50	3
Gemma gemma	29.00	2
Scoloplos sp.	24.50	3
Nematoda	24.00	3
Heteromastus filiformis	20.00	1
Mya arenaria	15.50	3
Polydora sp.	14.50	2
Nereis diversicolor	13.00	2
Lumbrineris brevipes	11.00	1
Notomastus latericeus	7.50	1
Littorina littorea	6.00	1
Mytilus edulis	6.00	2
Leucon nasicoides	4.50	1
Balanus balanoides	4.00	1
Polydora ligni	4.00	1
Tharyx acutus	3.50	1
Gammarus mucronatus	3.00	1
Nephtys caeca	3.00	1
Eteone longa	2.50	2
Pygospio elegans	2.00	1
Orchestia platensis	1.00	1

bars periodically. Mussel bars were not sampled specifically; however, they are composed mainly of dense accumulations of *Mytilus edulis* (the blue mussel), with the associated species being oligochaetes, nematodes, and polychaete worms. Where the bars are covering the surface of a flat, the normal infaunal components may be modified.

Mud flats are highly productive areas, both directly and indirectly. Maine's mud flats produce vast quantities of clams, bloodworms and sand worms which are harvested, sometimes excessively. Fish such as flounder feed in these areas also. Fauna inhabiting the mud flats are undoubtedly put under stress by the digging activities, which tend to disrupt orientation, depth, and "homes" (often tubes) of the resident animals. Particularly disruptive is digging during cold winter days, when the possibility of shell-ice formation exists. Exposure of a cold-blooded animal, which is normally protected by the sediment, to freezing temperatures is obviously destructive.

GRAVEL BEACHES

Beaches which are composed of "pure" gravel in a geologic sense are rare in Maine. However, it is necessary to examine distinct habitat types (i.e. ecological units) in order to be able to make any suppositions about the species that might be associated with combinations of habitat types, such as gravel-sand or cobble-gravel. In a cove, gravel (or sometimes gravel-sand) is often present at the inner and lower energy section of the cove. From the inner part of the cove to the point, gravel gives way to cobble, then to boulders, and then (although not always) to bedrock (Fig. 39). Energy levels, which account for the gradation of sediment type, increase along the gradient from inner cove to the exposed point. The best examples of this gradation are found in Penobscot Bay and to a lesser extent (due to the more complex energy structure) in Cobscook Bay. It should be noted that the lower relative energy level of a gravel beach may still be much higher than that found in flat environments (either mud or sand). Other areas in Maine, such as the sampling sites in Kittery, Bailey Island, and Perry, have more complex geologic and energy structures; however, they do generally grade from gravel to cobble.

Gravel is a relatively harsh environment in which to live. Although not as harsh as a sand beach with high exposure and shifting sands, the gravel is moved by waves, making it difficult for many attached species, including algae, to establish themselves in any abundance, or in some cases, to survive at all. This is reflected by the low species diversity (Table 1), which is second only to that of sand beaches.

Under the shifting surface gravel, however, is a relatively stable environment of sand and gravel where some infaunal species make their home. Although a total of 84 taxa were found, only three infaunal groups, oligochaetes, nematodes, and nemerteans, occurred at all sites (Appendix 3, Section 4).

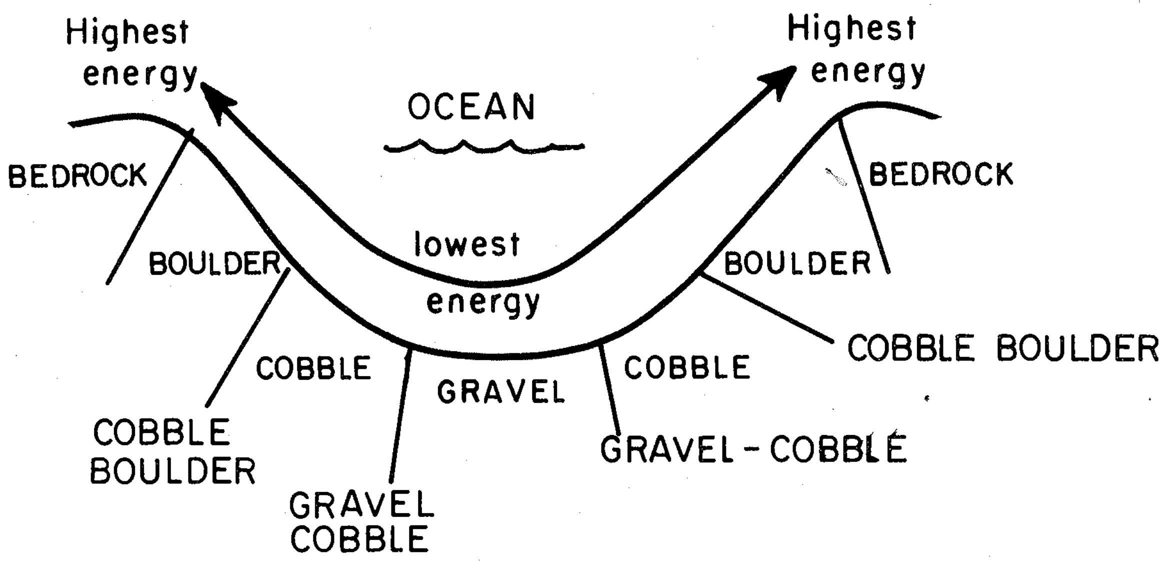

Figure 39. Schematic representation of the variations in sediment type along an energy gradient.

Oligochaetes, besides being present at all locations, were found at all tidal heights and were usually the most abundant taxon. This is reflected in the bioindex list (Table 6), where out of a possible score of 280 (if the taxon was first in abundance at every station), oligochaetes scored 243.5.

Although the mean number of species per station is about mid-range, the mean number of individuals per square meter (Table 2) is in the range of the highly diverse mud flat. The low diversity of gravel beaches reflects the fact that the individuals represent relatively few species. In other words, the animal that can survive the rigors of life on a gravel beach has a selection advantage and has the opportunity to increase its numbers without competition. This is to the advantage of non-specific species (ubiquitous) types, particularly the oligochaetes and nematodes, which appear first and second on the bioindex list.

Gravel beaches provide no direct economic benefit to Maine. However, since there is a predominance of oligochaetes (as many as 17,856 per square meter at one station) at gravel beaches, undoubtedly flounder find these areas favorable for feeding.

COBBLE BEACHES

Since cobbles are larger and heavier than gravel, they are found in relatively higher energy environments. Frequently these habitats are found side by side. At Perry, Kittery, and Bailey Island, good examples of gravel and cobble beaches exist next to each other, and they were sampled. As with gravel beaches, examples of "pure" cobble beaches are uncommon.

Although cobbles move when there is wave action, apparently at some locations they do not move as readily as gravel; hence more organisms are able to exist. As in gravel areas, the sediment under the surface consists of a mixture of sand and cobbles. On both cobble and gravel beaches storm waves throw the rocks up into the high intertidal zone, forming ridges. There is no question that storms wreak havoc on the animals living in these environments.

A total of 104 taxa were found in Maine's cobble beaches (Appendix 3, Section 5). As in gravel areas, oligochaetes and nematodes occurred at all sites. The ubiquitous isopod, *Jaera*, was also present at all cobble beaches sampled. A general comparison of the bioindex lists of gravel (Table 6) and cobble beaches (Table 7) reveals that there are many of the same species present on both lists, and the top four are in the same order.

Although the species diversity of cobble beaches is higher than that of gravel and sand beaches, it is still relatively low (Table 1). The mean number of species per station is only slightly higher than that of gravel; however, the mean number of individuals per square meter is much higher (by

Table 6. Bioindex values summated for all 7 gravel beach sites.

Organism	Total	Frequency
Oligochaeta	243.50	7
Nematoda	155.50	7
Balanus balanoides	68.00	4
Littorina littorea	42.50	4
Mytilus edulis	40.50	6
Nemertea	39.50	7
Orchestia platensis	37.50	5
Mite	20.50	5
Insecta - adult	20.50	4
Anurida maritima	18.16	3
Insecta - larva	18.00	2
Insecta - pupa	14.50	3
Sipunculida	13.00	1
Trichoptera - larva	11.00	4
Earwig	10.00	1
Jaera sp.	8.50	3
Nereis virens	8.16	3
Onoba aculeus	7.50	2
Dipteran - larva	5.50	1
Mya arenaria	5.50	3
Carcinus maenas	4.66	4
Acmaea testudinalis	3.50	2
Platyhelminthes	3.50	1
Chironomid - larva	3.00	1
Littorina obtusata	3.00	1
Coleoptera - adult	2.00	1
Corophium volutator	2.00	1
Orchestia grillus	2.00	1
Exogone hebes	1.50	1
Gemma gemma	1.50	1
Dipteran - pupa	1.00	1
Echinarachnius parma	1.00	1
Oenopota sp.	1.00	1
Spionid sp.	1.00	1
Dinophilus sp.	0.50	1
Gammarus oceanicus	0.16	1
Glycera dibranchiata	0.16	1

Table 7. Bioindex values summated for all 8 cobble beach sites.

Organism	Total	Frequency
Oligochaeta	222.00	8
Nematoda	128.50	8
Balanus balonoides	78.00	4
Littorina littorea	63.50	6
Orchestia platensis	59.00	6
Mytilus edulis	48.25	7
Marinogammarus stoerensis	34.00	2
Nemertea	32.00	4
Anurida maritima	30.00	2
Platyhelminthes	20.00	4
Littorina saxatills	17.50	3
Carcinus maenas	17.00	5
Jaera sp.	15.00	4
Marinogammarus finmarchicus	13.00	3
Gammarus oceanicus	11.00	3
Earwig	11.00	2
Sipunculida	11.00	1
Mite	9.00	2
Gammarus setosus	8.00	1
Nereis virens	6.50	2
Littorina obtusata	6.00	1
Strongylocentrotus droebachiensis	5.50	2
Insecta - adult	5.25	3
Polychaeta CC	5.00	1
Pseudoscorpion	5.00	1
Eteone longa	4.50	1
Chironomid larva	4.00	1
Thais lapillus	3.50	2
Onoba aculeus	3.00	1
Scolecolepides viridis	3.00	1
Mya arenaria	2.50	2
Lacuna vincta	2.50	1
Unknown Phylum - Platyhelminthes	2.00	1
Acmaea testudinalis	1.50	1
Eteone	1.50	1
Eteone trilineata	1.50	1
Trichoptera - larva	1.25	2
Glycera dibranchiata	1.00	1
Insecta - pupa	0.50	1
Pholoe minuta	0.50	1
Coleoptera - adult	0.25	1

about 3000/m^2) than at gravel locations (Table 2). As many as 87,096 *Balanus balanoides* (barnacles) and 21,836 oligochaetes per square meter were present at individual station locations. Although there is a great similarity in the number and type of species present, it is apparent that the species which do occur are able to occur in greater numbers than in a shifting gravel environment.

As in the gravel habitat, the species occurring on cobble beaches, with the exception of a few species occurring in low frequencies at single locations, were also present at other habitats. An interesting polychaete, *Pectinaria gouldii* (Fig. 11), which is not uncommon in the subtidal zone, was present in the lower intertidal zone of some gravel and cobble beaches.

The economic importance of cobble beaches is similar to that of gravel beaches, that is, indirectly through feeding by flounders. Since cobble beaches have more individuals per square meter, they can be more productive than gravel areas. There is a concern on the part of some people over cobbles being taken from beaches for souvenirs, since cobble beaches are not common in Maine; this activity actually has an impact on small cobble beaches.

BOULDER BEACHES

The size of boulders precludes their movement, except possibly during severe storms. With the exception of the Lincolnville site (which may be too exposed to fresh water runoff from the Penobscot River), attached algae are present. This alone makes the habitat significantly different from the algae-free habitats of cobble and gravel. Boulders are large and stable enough to provide a suitable substrate for attached species. The area between the boulders provides shelter for many species, and the sediment beneath and between the boulders provides a suitable environment for some infaunal species.

Boulder beaches are present at a number of locations in Maine. In Penobscot Bay, they are often the high-energy points of land. In other areas of the state they are usually next to bedrock promontories, in areas that have slightly lower energy levels (Fig. 36). For instance, at Mount Desert's Otter Point area, the bedrock cliffs give way to a boulder beach that becomes a cobble-gravel beach at the head of the cove.

A total of 144 taxa were found on boulder beaches (Appendix 3, Section 6). At a single site at Mount Desert, there were 103 taxa present, and 73 were found at a single station. Thirty species were found at this site exclusively, all in the low intertidal zone.

The following taxa occurred at all sites:

Platyhelminthes	Flat Worm
Nematodes	Hair Worm
Nemerteans	Ribbon Worm
Encrusting bryozoans	
Oligochaetes	
Acmaea testudinalis	Chinaman's Hat
Littorina littorea	Common periwinkle
Littorina obtusata	Smooth periwinkle
Littorina saxatilus	Rough periwinkle
Thais lapillus	Dog Whelk
Mytilus edulis	Blue Mussel
Balanus balanoides	Rock barnacle
Jaera sp.	Isopod
Gammarus oceanicus	Amphipod
Marinogammarus stoerensis	Amphipod
Carcinus maenas	Green crab

It is interesting to note that all of these species also occur on high-energy rocky shores. A number of species were found only on high-energy rocky shores and boulder beaches. They include the following:

Polychaetes	*Autolytus* sp.
	Harmothoe sp.
	Phyllodoce maculata
	Polycirrus sp.
Chiton	*Tonicella marmorea*
Nudibranch	*Dendronotus frondosus* (pictured)
Gastropod	*Margarites helicina*
Isopod	*Idotea balthica*
Starfish	*Henricia* sp.
Brittlestar	*Ophiopholis aculeata* (pictured)

Diversity on boulder beaches is relatively high; however, it is lower than that of mud flats (Table 1). Although the diversity figure for high-energy rocky shores is based on only one site, it probably correctly reflects the relative diversities on a general level. Therefore, high-energy rocky shores would be expected to have a lower diversity than boulder beaches. Boulder beaches have more sub-habitats, since they have the potential for some infaunal development. Even though the mean number of individuals per square meter (Table 2) is relatively high, it is vastly lower than that of high-energy rocky shores. Since the huge numbers of individuals usually represent a limited number of species such as mussels, nematodes, and barnacles, the diversity is reduced overall on high-energy rocky shores. The mean number of species per station on boulder beaches is high and is just slightly lower than that found at high-energy rocky shores (Table 2).

Oligochaetes still rank first on the bioindex list (Table 8). Many of the species on the list are the same as those typically found on high-energy rocky shores, however, and the top three species are the same as those listed for cobble and gravel beaches, although not in the same order. The highest recorded abundances at individual stations are generally lower, with the exception of barnacles (which are higher than at gravel and lower than at cobble), than in cobble and gravel areas.

A number of interesting species were found on boulder beaches:

Nudibranchs (shell-less gastropods)
Ancula gibbosa
Onchidoris aspersa
Doto coronata

Echinoderms: sea cucumbers
Chiridota laevis (Fig. 40)
Cucumaria frondosa (Fig. 40)

Echinoderms: brittle star
Amphipholis squamata (Fig. 41)

Spider crab - juvenile
Hyas coarctatus

Pycnogonids: sea spiders
Achelia spinosa
Nymphon grossipes
Pycnogonum littorale (Fig. 42)
Phoxichilidium femoratum

These animals undoubtedly also occur subtidally and at some high-energy rocky shore locations.

There is no direct economic benefit provided by boulder areas except possibly the collection of the often dense growths of the rockweed, *Ascophyllum*. Since there are so many species present, predators which move into the intertidal zone during high tide probably can find suitable nourishment.

LOW-ENERGY ROCKY SHORES

Bedrock areas which generally are protected from wave action are considered to be low-energy rocky shores. The habitat is present in coves which have a narrow enough width so that waves cannot build up to any extent and a shore not exposed to the open ocean. Although there are many low-energy rocky shores along Maine's irregular coast, most of them drain to expose mud flats at low tide. Therefore, finding suitable sampling sites was difficult.

Table 8. Bioindex values summated for all boulder beach sites sampled.

Organism	Total	Frequency
Oligochaeta	151.00	6
Balanus balanoides	97.00	5
Nematoda	96.50	6
Mytilus edulis	37.50	5
Littorina Littorea	30.00	5
Littorina saxatilis	30.00	5
Littorina obtusata	26.00	5
Hyale nilssoni	19.00	3
Fabricia sabella	16.00	2
Marinogammdrus obtusatus	11.00	3
Jaera sp.	8.00	4
Marinogammarus stoerensis	8.00	3
Onoba aculeus	6.00	2
Nemertea	5.50	4
Orchestia platensis	5.00	1
Carcinus maenas	4.75	2
Ampithoe rubricata	4.00	1
Dipteran Larva	4.00	1
Mya arenaria	4.00	1
Acmaea testudinalis	4.00	1
Marinogammarus finmarchicus	3.00	2
Anurida maritima	3.00	1
Ischyrocerus anguipes	3.00	1
Lacuna vincta	3.00	1
Orchestia grillus	2.50	1
Mite	2.25	1
Chironomid Larva	2.00	1
Gammarus oceanicus	2.00	1
Thais lapillus	2.00	1
Sipunculida	2.00	1
Orchestia sp.	1.50	1
Platyhelminthes	1.25	2
Gammarus duebeni	1.00	1
Hiatella arctica	0.25	1

Figure 40. Two sea cucumbers found on boulder beaches, *Cucumaria frondosa* (left) and *Chiridotea laevis* (right).

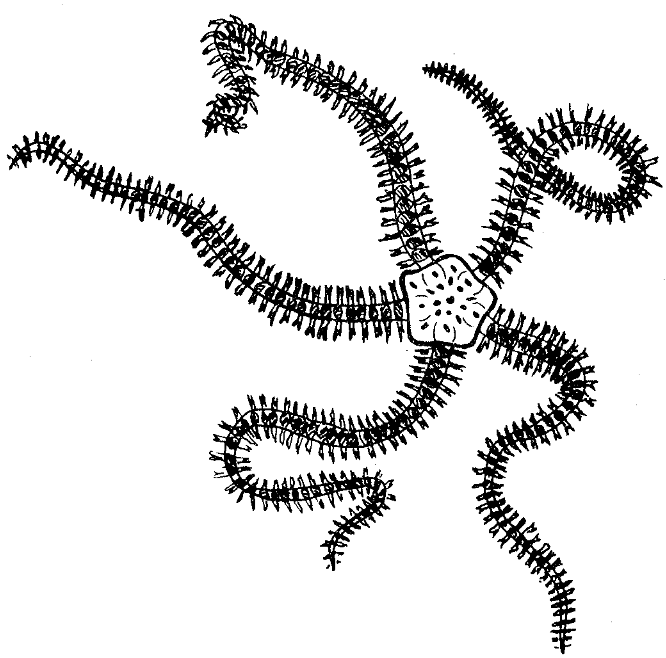

Figure 41. The brittle star *Amphipholis squamata*, found associated with sponges and kelp holdfasts.

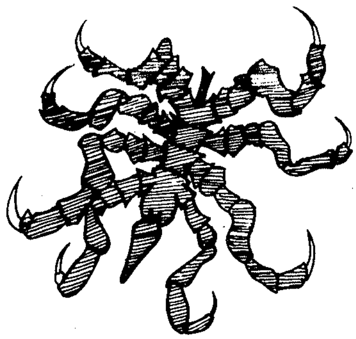

Figure 42. *Pycnogonum littorale* is a representative of the sea spiders and is one of four such species found in this study.

Figure 43. The shell-less gastropod *Dendronotus frondosus*, found on high-energy rocky shores.

The total number of taxa collected on low-energy rocky shores was 68 (Appendix 3, Section 7). Fewer species are present here than on high-energy rocky shores because of a greater range of environmental conditions (i.e. warmer in the summer and colder with possible ice formation in the winter) and greater turbidity. Most of the low-energy rocky shore areas sampled had a layer of silt coating the surface of the rocks and the attached algae. The following ubiquitous taxa were present at all completed sites:

Nematoda	
Nemertea	
Oligochaeta	
Acmaea testudinalis	Chinaman's hat (limpet)
Littorina littorea	Common periwinkle
Littorina obtusata	Smooth periwinkle
Mytilus edulis	Blue mussel
Balanus balanoides	Rock barnacle
Jaera sp.	Isopod
Carcinus maenas	Green crab

Mites, chironomid (midge) larva, and *Marinogammarus obtusatus* (an amphipod) also occurred at all sites.

The diversity of this habitat falls between gravel and cobble beaches and is relatively low (Table 1). The mean number of species per station is higher than for habitats of unconsolidated sediments, except for mud flats, and lower than at both boulder beaches and high-energy rocky shores (Table 2). The mean number of individuals per square meter is also lower than for high-energy rocky shores and boulder beaches (Table 2).

Oligochaetes for the first time take second place to barnacles on the bioindex list (Table 9). (Barnacles are also high on the list for high-energy rocky shores.) Also high on the list are the ubiquitous periwinkles (*Littorina*), nematodes, and *Jaera* (the isopod).

Faunistically there is little potential economic value in the low-energy rocky shore habitat, with the possible exception of periwinkle harvesting. However, there are dense growths of *Ascophyllum* at some of the low-energy locations that may be abundant enough to harvest. Since there are fewer species and less wave action (to wash animals away) at this habitat, harvesting algae and associated activities (i.e. foot traffic) are probably less detrimental than on high-energy rocky shores.

HIGH-ENERGY ROCKY SHORES

Maine's coast north of Cape Elizabeth is characterized by bedrock areas that are exposed to waves. There is more bedrock on the coast of Maine than any other habitat type. The highest-energy areas are at the headlands, such as Two Lights,

Table 9. Bioindex values summated for all 5 low-energy rocky shore sites sampled.

Organism	Total	Frequency
Balanus balanoides	124.00	5
Oligochaeta	94.00	6
Littorina obtusata	45.00	5
Jaera sp.	39.50	6
Nematoda	38.50	6
Littorina littorea	33.25	5
Mytilus edulis	32.50	4
Spirorbis borealis	23.00	3
Littorina saxatilis	20.00	2
Hyale nilssoni	14.00	3
Marinogammarus obtusatus	13.50	3
Anurida maritima	12.00	2
Mite	10.50	2
Nemertea	9.25	3
Chironomid Larva	9.00	2
Platyhelminthes	9.00	1
Acmaea testudinalis	8.00	1
Onoba aculeus	6.00	2
Naineris quadricuspida	4.00	1
Carcinus maenas	3.00	1
Ampithoe rubricata	2.75	2
Asterias sp.	2.00	1
Fabricia sabella	2.00	1
Marinogammarus stoerensis	2.00	1
Anomia simplex	1.50	1
Chironomid Pupa	1.00	1
Skeneopsis planorbis	0.50	1

Cape Elizabeth, Bailey Island, or Quoddy Head, Lubec. This was the type of area sampled.

High-energy rocky shores have four distinct zones, discussed in the section on zonation. The upper intertidal zone has few species, which are present in relatively low numbers; however, the other three zones have exceptionally high numbers of individuals per square meter (which includes the high intertidal zone). The mean number of individuals at Bailey Island is 54,896 (Table 2), over four times any other habitat. In the barnacle zone, there were almost 160,000 per square meter at a single station. Because of the great number of individuals present, the samples from high-energy rocky shores are difficult to sort; the animals must be separated from a tangled conglomeration of algae and clumps of mussels with interlocking byssal strands. For these reasons, we were able to process fully only the Bailey Island site. We have been able to supplement the data with qualitative data that were collected on a project funded by the Critical Areas Program of the State Planning Office.

We find ninety (90) taxa when we combine data from both studies (Appendix 3, Sections 8 + 9). Sixty-three (63) taxa were found at the Bailey Island site, although the highest number of species found in the qualitative survey was forty. This may indicate that some small species, such as polychaetes and amphipods, were overlooked in the qualitative survey.

The following taxa are characteristic of specific zones of Maine's high-energy rocky shores:

High intertidal zone:	*Littorina saxatilis* (tiny periwinkle) *Anurida maritima* (springtail)
Barnacle zone:	*Balanus balanoides* (Rock barnacle) *Mytilus edulis* (Blue mussel)
With the following associated animals:	*Hyale nilssoni* (amphipod) Oligochaeta Nematoda
Rockweed zone:	*Littorina littorea* (Common periwinkle) *Littorina obtusata* (Smooth periwinkle) *Acmaea testudinalis* (Chinaman's Hat, limpet) *Thais lapillus* (Dog whelk) *Mytilus edulis* (Blue mussel) *Modiolus modiolus* (Horse mussel) *Balanus balanoides* (Rock barnacle)

Chondrus zone:	*Halichondria panicea* (green sponge)
	Encrusting bryozoans
	Tonicella marmorea (chiton)
	Acmaea testudinalis (Chinaman's Hat)
	Littorina littorea (Common periwinkle)
	Lacuna vincta (gastropod)
	Hiatella arctica (arctic clam)
	Lepidonotus squamata (scaleworm)
	Oligochaeta
	Balanus balanoides (Rock barnacle)
	Gammarus angulosus (amphipod)
	Carcinus maenas (green crab)
	Asterias vulgaris (starfish)

Other species which are commonly found in the *Chondrus* zone, although less frequently, are anemones, various nudibranchs (shell-less gastropods) such as *Dendronotus frondosus* (Fig. 43), *Cancer irrorstus* (rock crab), *Henricia* (blood starfish), *Ophiopholis aculeata* (brittle star) and *Strongylocentrotus droebachiensis* (sea urchin).

The reason that so many of the same species can be expected to occur at most high-energy bedrock locations is that these areas experience relatively constant conditions of salinity and temperature. Also, there are numerous subhabitats in the form of pools, cracks, and crevices which support a diverse group of animals.

Mytilus edulis and *Balanus balanoides* head the bioindex list (Table 10), and probably would at other high-energy rocky shore locations.

Although the mean number of species per station is higher than at the other habitats (Table 2), the diversity is mid-range (1.52) (Table 1). It is low because the number of individuals of a few species is very high (see discussion on diversity in analysis section).

Animals living on high-energy rocky shores are able to survive the stress of pounding surf; however, they have little or no protective mechanism to resist being crushed by foot traffic and consequently being washed away. Since most of the species living in this habitat are epifaunal (i.e., living on the surface), they are obviously more susceptible to being crushed than those animals living in other habitats. Ironically, this habitat probably experiences more foot traffic than any other, with the exception of sand beaches.

Harvesting of periwinkles, algae (*Ascophyllum* and *Chondrus*), and mussels occurs in this habitat. Periwinkles play an important role by grazing the rock surface. Overharvesting can disrupt the ecological balance of high-energy rocky shores. Algae and mussel harvesting are particularly detrimental because algae and mussels provide shelter for a variety of species. Harvesting can cause a decrease in species diversity.

Table 10. Bioindex values for Bailey Island high-energy rocky shore

Organism	Total (only one site)
Mytilus edulis	25
Balanus balanoides	18
Nematoda	13
Littorina saxatilis	8
Hyale nilssoni	7
Anurida maritima	5
Lacuna vincta	4
Littorina littorea	4
Jaera sp.	3
Oligochaeta	3
Jassa falcata	3
Hiatella arctica	3
Littorina obtusata	3

SALT MARSHES

Salt marsh areas in Maine range from fringe marsh at the heads of many mud flats to the broad expanses of marsh found at the Scarborough Marsh, which has been said to include 20% of Maine's marsh area. Marshes are of particular interest because they provide refuge for diverse groups of waterfowl and seabirds. Eagles, egrets, herons, ibises, ospreys, willets, and various sandpipers were among the groups noticed while sampling the marsh areas.

Marshes south of Maine have been extensively studied, particularly in Rhode Island, Virginia, and Georgia. The information gleaned from these studies has been extrapolated geographically in order to make pronouncements and decisions about Maine marshes. Such extrapolations, however, depend upon unverified assumptions. Maine marshes undoubtedly play an important role in the marine ecosystem, but not necessarily in the ways that are usually quoted.

There are a few obvious differences between Maine and the areas south of Cape Cod which should be noted. The climate, including water temperature, is different (i.e. colder); hence Maine has more boreal or arctic species. Because of the climate, the growing season is shorter. Marsh grasses, as well as standard agricultural crops, are affected by a reduced growing season. The classic productivity studies in Georgia are based on two crops of marsh grass per year. It is doubtful that there is a long enough (or warm enough) growing season for two crops to grow here. The tides in Maine have a greater range than those to the south. This may have the effect of providing greater "flushing power", which consequently would contribute more nutrients on a more regular basis to the oceanic system than in non- or infrequently flushed areas.

The "nursery theory" that is attributed to salt marshes should be examined closely in relation to Maine's marshes. Yes, some species do spend their juvenile stages in salt marsh creeks, but certainly not lobsters or the species of shrimp which is harvested commercially.

It is obvious that much thorough scientific work needs to be conducted on Maine's salt marshes in order to answer some very basic questions about their function. The following questions should be addressed:

- What is the productivity of Maine's marshes?
- How does this productivity relate to the oceanic system?
- What species actually do live in the salt marsh creeks, and how do they relate to the marsh and the marine ecosystem?

Before we make further pronouncements, pro or con, about salt marsh activities such as ditching, impoundments, or filling, we should find out how the system works.

Since processing the type of salt marsh samples which were collected for this study is extremely time consuming, to date only one site has been worked up. Further salt marsh work requires a program which concentrates on this habitat alone, instead of a broad-based survey approach. There were 28 types of animals present at the Yarmouth site (Appendix 3, Section 10). From general observation of the other marsh sites sampled, this one is relatively rich faunistically.

Oligochaetes and nematodes head the bioindex list (Table 11) and most certainly would have ranked high at the other sites. The third highest species, *Nereis diversicolor*, is the same genus as (i.e. related to) the sand worm, *Nereis virens*; however, *Nereis diversicolor* is found in areas of reduced salinity, such as the upper reaches of mud flats, up-estuary, and on the banks of salt marshes.

Since parts of the salt marsh (i.e. *Spartina patens* zone) are not submerged with every tide and the entire marsh is relatively high, the areas sampled at this habitat (see methods section) are not really comparable to the other eight habitats. Therefore, comparisons with other habitats of diversity, mean number of species per station, and mean number of individuals per square meter (Tables 1 and 2) are not really valid, but are included for completeness.

Two species found exclusively at marshes were the amphipod *Orchestia uhleri* and the snail *Melampus bidentatus*. Both these species were found in the high *Spartina alterniflora* zone. Since this zone is not regularly inundated by tides, these animals have developed adaptive behavior. *Melampus bidentatus* can breath air and climbs up and down the *Spartina* stems. *Orchestia uhleri* hides around the roots of *Spartina* and also climbs the stems when the tide is in over the grass. Another typical salt marsh species is *Modiolus demissus* (ribbed mussel). Although this species was not found at the Yarmouth site, it has been noted commonly in other salt marsh areas, including fringe marshes around flats.

Although salt marshes provide little in direct economic benefit, they are probably playing a large role indirectly by providing nutrients and organic detritus to the oceanic system. Maine's salt marshes, although limited in acreage, are beautiful aesthetically.

GENERAL HABITAT COMMENTS

As mentioned previously, there are numerous combinations of habitat types in Maine. By delineating which and how many species are present at specific habitat types, one can interpolate as to what species might occur at mixed habitat types. Besides mixed horizontal habitat types (i.e. gravel-cobble, gravel-sand), there are numerous cases of vertical changes in habitat type. Typically, the upper intertidal zone of

Table 11. Bioindex values for Cousins River salt marsh, Yarmouth

Organism	Total (only one site)
Oligochaeta	26.00
Nematoda	15.00
Nereis diversicolor	11.00
Hydrobia sp.	6.67
Macoma balthica	6.00
Dipteran Larvae	5.50
Orchestia grillus	5.17
Chironomid Larva	3.00
Pygospio elegans	2.00
Mite	2.00
Littorina saxatilis	2.00
Insecta - adult	1.67
Arachnid	1.50
Nemertea	1.00
Polydora sp.	0.25
Mya arenaria	0.25
Corophium volutator	0.25
Capitella capitata	0.25
Gastropod - unidentified	0.17
Coleoptera - adult	0.17

flats is either fringe marsh or low-energy rocky shore. The animals present in these areas are similar to those found at comparable tidal heights on low-energy rocky shores or *Spartina alterniflora* areas of marsh.

As one goes from the high-energy rocky shore headlands into the bays and inlets of Maine's irregular coast, the energy level (i.e. wave action) decreases, and therefore the intertidal zone becomes narrower and smaller in area (see Fig. 1). The total number of individuals is greatly decreased, mainly because the densely populated barnacle zone is reduced. The mean number of species per station is reduced along the energy gradient, but the types of species encountered are basically the same.

It should be pointed out that although mud flats have a relatively high diversity for intertidal areas, the diversity of subtidal regions is much higher. Diversity figures were as high as 4 in the shallow subtidal areas of the Sheepscot River (Larsen, 1979) as opposed to 2.33 for mud flats. The subtidal zone is a more constant environment; hence it is more diverse. Many intertidal animals that would have difficulty competing with the other species in the subtidal zone flourish because they can adapt to the intertidal stresses. As was noted in the discussion on diversity (see Analysis section), a large number of individuals of a few species, as found in the intertidal zone, have a lower diversity than fewer individuals of a greater number of species, as found in the subtidal zone.

Sand beaches have the lowest mean number of species per station, lowest mean diversity per station, and lowest mean number of individuals per square meter for all habitats (Figs. 44,45,and46). High-energy rocky shore has the highest mean number of species per station (Fig.44) and by far the highest mean number of individuals per square meter (Fig.46). Mud flats have a higher diversity because, although there is a greater mean number of species per station on high-energy rocky shores, the huge numbers of individuals of a limited number of species (such as is the case with mussels and barnacles) reduces the diversity figure. As one goes from sand beach to gravel beach to cobble beach to boulder beach, there is an increase in the three parameters (Tables 44, 45, and 46). This can be interpreted to mean that as the relative particle size increases, there is less movement of the sediment by wave action; therefore, more individuals of more types of species can survive. In the relatively quiet (energy-wise) flat environment, mud flats consistently have individuals of more species than sand flats. The greater organic material of mud flats, in addition to the finer sediment (more silt-clay than sand), make this habitat more favorable for more animals to make their "homes". Low-energy rocky shores also have relatively lower means of numbers of species, diversity, and density (Figs. 44, 45, and 46) than high-energy rocky shores. The means from areas between the

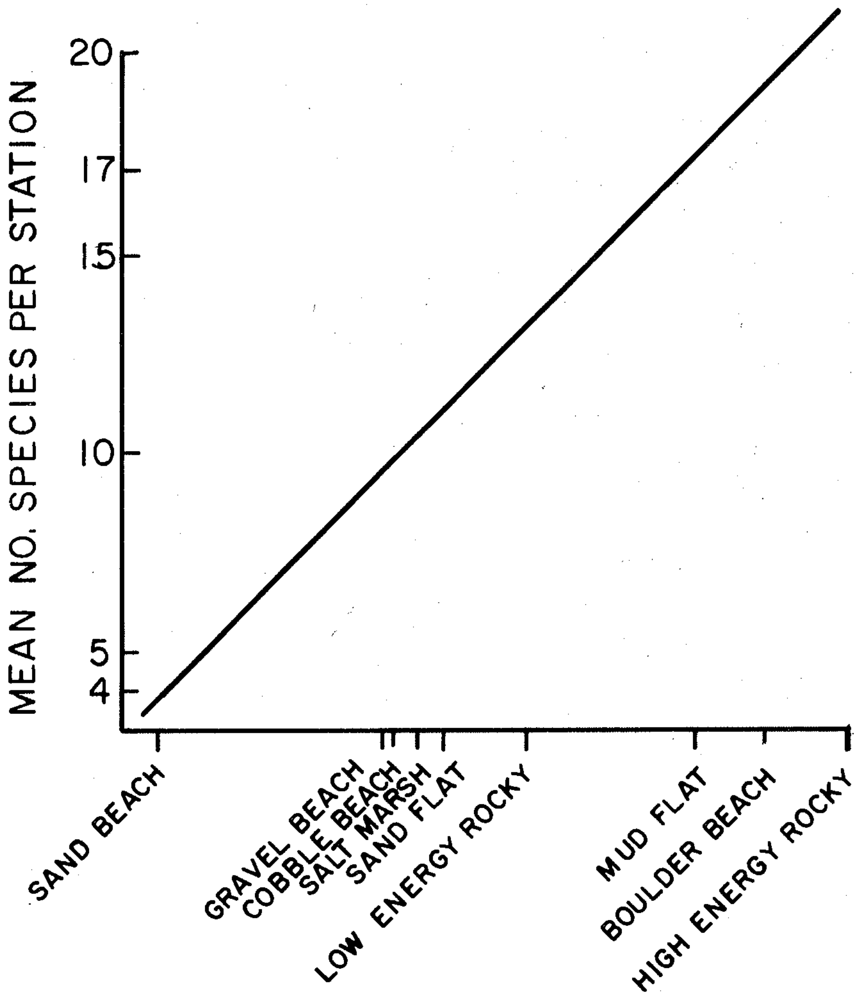

Figure 44. The mean number of species per station of each habitat sampled.

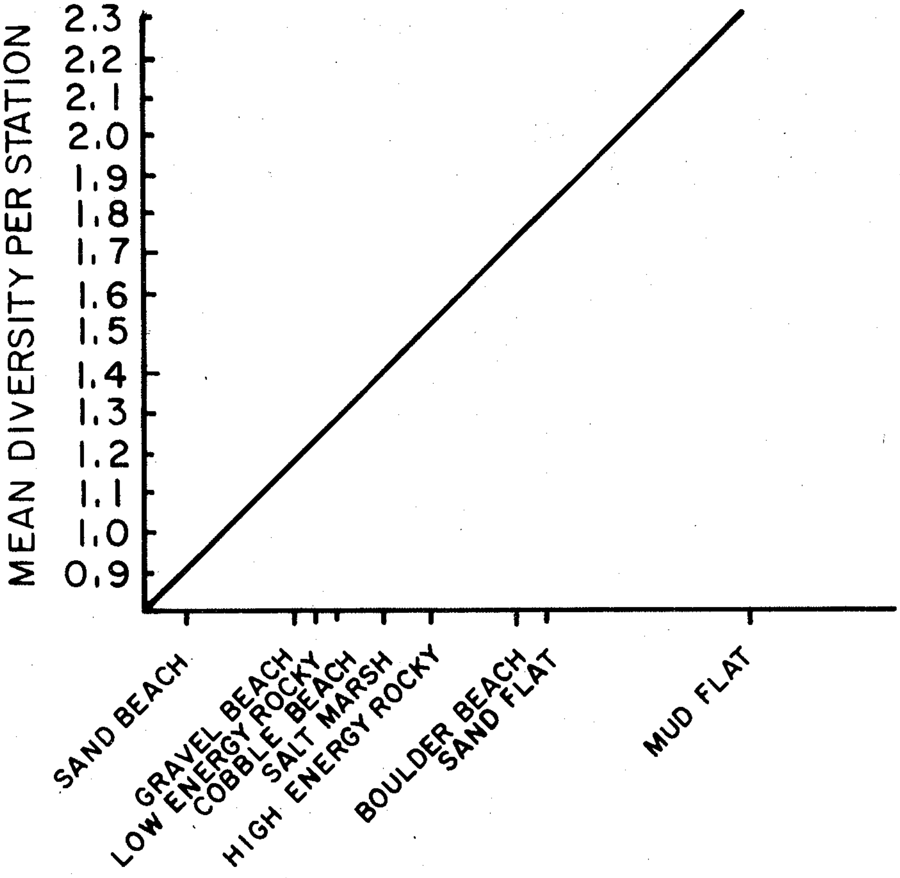

Figure 45. The mean diversity per station of each habitat sampled.

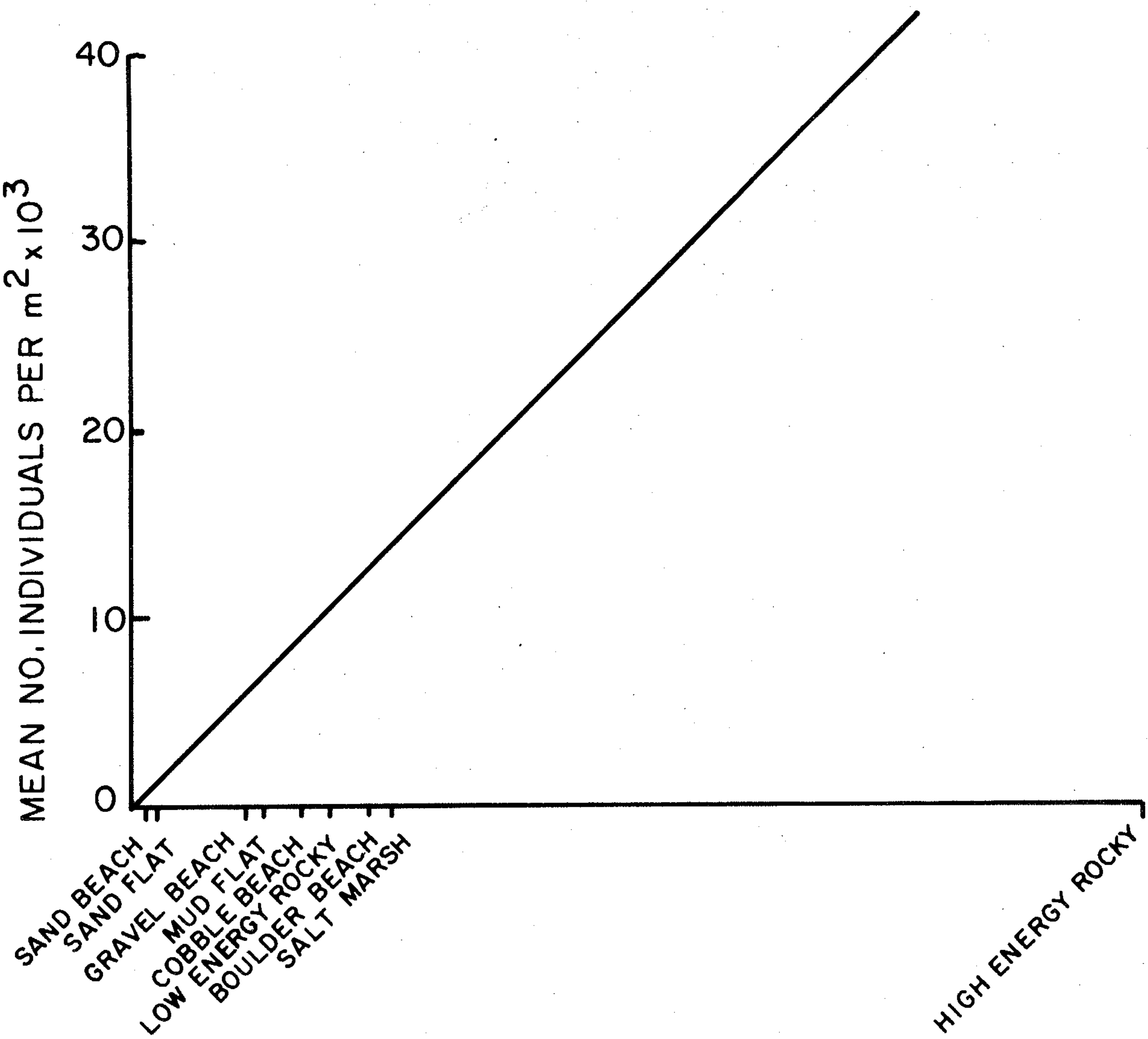

Figure 46. The mean number of individuals per square meter of each habitat sampled.

high-energy headlands and the low-energy coves follow a gradient in relation to energy level.

Some species prefer relatively stable substrates (but not flat environments), but are not particular about energy levels. *Cancer irroratus* (rock crab), *Molgula* (tunicate), *Strongylocentrotus droebachiensis* (sea urchin), *Asterias* (starfish), *Lepidonotus squamatus* (scale worm), *Ampithoe rubricata* (amphipod), *Dexamine thea* (amphipod), and *Eteone trilineata* (polychaete) are found on cobbles, boulders, and rocky shores of varying energy levels.

APPENDIX 1

HABITATS WITH DATE SAMPLED

Mud Flat

Kittery	July 29, 1976
Mussel Cove, Falmouth	May 15, 1975
Hodgdon Cove, Boothbay Harbor	May 8, 1975
East Friendship	June 3, 1975
*Stockton Springs	May 20, 1975
*Mt. Desert Island	June 9, 1976
Addison	June 21, 1976
*Perry	June 23, 1976

Sand Flat

Kittery	July 17, 1976
Wells	July 16, 1976
Heal Eddy, Georgetown	May 25, 1975
Rockport	July 12, 1975
Trescott Township	June 26, 1976

Sand Beach

Kennebunkport	July 13, 1976
Scarborough	July 12, 1976
Reid-Georgetown	May 17, 1975
Pemaquid-Bristol	May 22, 1975
Lincolnville	May 19, 1975
Mt. Desert Island	June 12, 1976
Jonesport	June 20, 1976
Roque Bluffs	June 19, 1976

Gravel Beach

Kittery	July 27, 1976
Bailey Island	July 14, 1975
Friendship	July 23, 1975
Temple Heights	June 14, 1975
Mt. Desert Island	June 8, 1976
Machiasport	June 18, 1976
Perry	June 24, 1976

Cobble Beach

Kittery	July 27, 1976
Kennebunkport	July 28, 1976
Bailey Island	June 15, 1975
Owl's Head	July 17, 1975
Lincolnville	July 15, 1975
Mt. Desert Island	June 10, 1976
Lubec	June 22, 1976
Perry	June 24, 1976

Boulder Beach	
Wells	July 26, 1976
Bailey Island	July 20, 1975
St. George	July 24, 1975
Lincolnville	July 27, 1975
Mt. Desert Island	June 13, 1976
Roque Bluffs	June 27, 1976
Low-Energy Rocky	
East Harpswell	July 26, 1975
Boothbay Harbor	July 10, 1975
Waldoboro	July 19, 1975
Mt. Desert Island	June 12, 1976
Machiasport	June 18, 1976
Dennysville	June 27, 1976
High-Energy Rocky	
*Cape Neddick	July 15, 1976
*Cape Elizabeth	July 14, 1976
Bailey Island	June 29, 1975
*Boothbay Harbor	June 28, 1975
*Port Clyde	June 27, 1975
*Mt. Desert Island	June 11, 1976
*Roque Bluffs	June 28, 1976
*Lubec	June 22, 1976
Salt Marsh	
*Scarborough	July 12, 1976
Cousins River, Yarmouth	May 29, 1975
*Addison	June 21, 1976

*Samples not completely worked up.

APPENDIX 2

List of all taxa found during the two year sampling program. Species are in alphabetical order within the higher taxa, which are in phylogenetic order.

Phylum Porifera

Porifera Unidentified

Phylum Cnidaria

Class Hydrozoa

Hydrozoa Unidentified

Sertularia - wreathed hydroid

Class Anthozoa

Anthozoan Unidentified

Bunodactis stella - sea anemone

Edwardsia elegans - sea anemone

Phylum Platyhelminthes

Platyhelminthes Unidentified - flat worms

Phylum Rhynchocoela

Nemertea Unidentified - proboscis or ribbon worms

Phylum Aschelminthes

Nematoda Unidentified - round worms

Phylum Bryozoa

Bryozoa Unidentified - moss animals

Bryozoa Encrusting - moss animals

Flustrellidra

Phylum Mollusca

Class Polyplacophora - chitons

Tonicella marmorea - chiton

Class Gastropoda - snails and slugs

Gastropoda Unidentified - snails

Subclass Prosobranchia

Acmaea testudinalis	- tortoise-shell limpet
Buccinum undatum	- waved whelk
Crepidula convexa	- gray slipper shell
Crepidula fornicata	- boat shell or slipper shell
Hydrobia	- spire shells
Lacuna vincta	- Atlantic chinic shell
Littorina littorea	- Common periwinkle
Littorina obtusata	- Smooth periwinkle
Littorina saxatilis	- Rough periwinkle
Margarites helicina	- Smooth top shell
Nassarius obsoletus	- Mud snail
Nassarius trivittatus	- New England nassa
Odostomia	- Pyramid shells
Odostomia bisuturalis	
Oenopota	
Onoba aculeus	
Polinices heros	- Moon snail
Polinices triseriata	- Moon snail
Skeneopsis planorbis	- Orb shell or trumpet shell
Thais lapillus	- Dog whelk

Subclass Opisthobranchia	- Nudibranchs or shell-less gastropods
Ancula gibbosa	
Dendronotus frondosus	- Bushy back slug
Doto coronata	- Crowned sea slug
Onchidoris	
Onchidoris aspersa	
Onchidoris fusca	

Subclass Pulmonata

Melampus bidentatus - Eastern melampus

Class Bivalvia

Anomia aculeata - Mermaid's toenail, spiny or thorny jingle shell

Anomia simplex - Mermaid's toenail, smooth or plain jingle shell

Bivalve D

Crenella decussata

Crenella faba - Little bean mussel

Crenella glandula - Glandular bean mussel

Ensis directus - Razor clam

Gemma gemma - Amethystine gem shell

Hiatella arctica - Arctic rock borer

Macoma balthica - Little macoma

Modiolus demissus - Ribbed mussel

Modiolus modiolus - Horse mussel

Mya arenaria - Long neck clam or soft-shell clam

Mytilus edulis - Blue or edible mussel

Petricola pholadiformis - Rock borer

Spisula solidissima - Surf clam

Tellina agilis - Sunset shell

Phylum Annelida - Segmented worms

Class Polychaeta - Bristleworms

Family dinophilidae - Archiannelida

Dinophilus

Family Phyllodocidae

Eteone

Eteone heteropoda

Eteone longa

Eteone trilineata

Eumida sanguinea

Phyllodoce

Phyllodoce arenae

Phyllodoce groenlandica

Phyllodoce maculata

Phyllodoce mucosa

Phyllodocid

Family Polynoidae - Scale worms

Eucranta villosa

Harmothoe

Harmothoe extenuata

Harmothoe imbricata

Lepidonotus squamatus

Polynoid

Polynoid Juvenile

Family Sigalionidae

Pholoe minuta

Family Glyceridae

Glycera dibranchiata - Blood worm

Family Nephtyidae

Aglaophamus verrilli

Nephtys bucera

Nephtys caeca

Nephtys ciliata

Nephtys incisa

Nephtys longosetosa

Nephtys picta - Painted worm

Family Syllidae

Autolytus

Exogone hebes

Exogone verugera

Syllidae

Syllid A

Syllid B

Syllis

Syllis gracilis

Family Hesionidae

Microphthalmus sczelkowii

Family Nereidae

Nereis - Rag worm

Nereis diversicolor

Nereis succinea

Nereis virens- Sandworm

Family Capitellidae

Capitella capitata

Heteromastus filiformis

Notomastus latericeus

Family Arenicolidae

Arenicola cristata - Lug worm

Family Maldanidae - Bamboo worms

Clymenella torquata

Maldanid

Maldanopsis elongata

Nichomache lumbricalis

Family Opheliidae

Ophelia

Family Spionidae

Polydora

Polydora ligni

Pygospic elegans

Scolecolepides viridis

Scolelepis squamata

Spio

Spio filicornis

Spio setosa - bi-tentacled worm

Spionid

Spiophanes bombyx

Streblospio benedicti

Family Paraonidae

Aricidea jeffreysii

Paraonis fulgens

Family Lumbrinereidae

Lumbrineris brevipes

Lumbrineris fragilis

Ninoe nigripes

Family Orbiniidae

Orbinia

Naineris quadricuspida

Scoloplos

Family Cirratulidae

Cirratulid

Cirratulus cirratus

Cirratulus grandis - Fringed worm

Tharyx

Tharyx acutus

Family Pectinariidae - Cone worms

Pectinaria gouldii

Pectinaria granulata

Family Ampharetidae

Ampharete acutifrons

Ampharete arctica

Ampharetid A

Ampharetid B

Ampharetid C

Family Terebellidae

Amphitrite cirrata

Amphitrite johnstoni

Loimia

Nicolea

Pista cristata

Polycirrus

Terebellidae

Family Flabelligeridae

Diplocirrus hirsutus

Pherusa

Pherusa affinis

Pherusa plumosa

Family Sabellidae - Feather-duster worms or fanworms

Fabricia sabella

Myxicola infundibulum

Family Serpulidae - Feather-duster worms or fanworms

Spirorbis borealis - Coiled worm

Family Unknown

Polychaeta A

Polychaeta BB

Polychaeta CC

Polychaeta Unidentified

Class Oligochaeta - Aquatic earthworms

Oligochaeta

Phylum Sipuncula

Sipunculida

Phylum Arthropoda

Subphylum Pycnogonida - Sea spiders

Achelia spinosa

Nymphon grossipes

Phoxichilidium femoratum

Pycnogonum littorale

Subphylum Chelicerata

Class Arachnida

Arachnid Unidentified

Mite

Pseudoscorpion

Subphylum Mandibulata

Class Crustacea

Subclass Ostracoda

Ostracoda Unidentified - Seed shrimp

Subclass Cirripedia - Barnacles

Balanus balanoides -Rock barnacle

Balanus balanus

Balanus crenatus

Subclass Malacostraca

Order Cumacea

Diastylis polita

Eudorella emarginata

Eudorella truncatula

Leptocuma minor

Leucon nasicoides

Oxyurostylis smithi

Order Tanaidacea

Leptochelia rapax

Leptognatha

Order Isopoda - Aquatic sow bugs

Chiridotea coeca

Chiridotea tuftsi

Edotea triloba

Idotea balthica

Idotea phosphorea

Jaera

Philoscia vittata

Order Amphipoda - Beach fleas, hoppers, sideswimmers

Family Ampeliscidae

Ampelisca abdita

Ampelisca vadorum

Family Ampithoidae

Ampithoe rubricata

Family Aoridae

Microdeutopus gryllotalpa

Family Calliopidae

Calliopius

Calliopius laeviusculus

Family Corophiidae

Corophium insidiosum

Corophium volutator

Unciola irrorata

Family Dexaminidae

Dexamine thea

Family Gammaridae - Scuds

Gammarellus angulosus

Gammaridae

Gammarus

Gammarus duebeni

Gammarus lawrencianus

Gammarus mucronatus

Gammarus oceanicus

Gammarus setosus

Marinogammarus finmarchicus

Marinogammarus obtusatus

Marinogammarus stoerensis

Family Haustoriidae

Amphiporeia virginiana

Acanthohaustorius millsi

Haustorius canadensis

Pontoporeia

Protohaustorius deichmannae

Family Hyalidae

Hyale nilssoni

Family Ischyroceridae

Ischyroceros anguipes

Jassa falcata

Family Lysianassidae

Psammonyx nobilis

Family Phoxocephalidae

Harpinia propinqua

Phoxocephalus holbolli

Family Pontogeneiidae

Pontogeneia inermis

Family Talitridae

Orchestia

Orchestia grillus

Orchestia platensis

Orchestia uhleri

Talorchestia megalophthalma

Family Caprellidae - Skelton shrimp

Aeginina longicornis

Caprella penantis

Luconacia

Paracaprella tenuis

Order Mysidacea

Mysid - Opossum shrimp

Order Decapoda

Cancer irroratus - rock crab

Carcinus maenas - green crab

Crab Megalops

Crab Zoea

Crangon septemspinosa - sand shrimp

Hyas coarctatus - toad crab

Pagurus - hermit crab

Class Insecta - insects

Insecta Adult

Insects Larva

Insecta Pupa

Order Collembola - springtails

Anurida maritima

Order Dermaptera

Earwig

Order Trichoptera - caddis fly

Trichoptera Larva

Order Diptera - flies, mosquitoes, and midges

Ceratopogonidae - biting midge

Chaeborus - phantom midge

Chironomid Larva - midge

Chironomid Pupa - midge

Dipteran Larva

Dipteran Pupa

Order Coleoptera - beetles

Coleoptera Adult

Order Hymenoptera

Ant

Class Chilopoda

Centipede

Class Diplopoda

Millipede

Phylum Echinodermata

Class Holothuroidea - sea cucumbers

Chiridota laevis - tufted synapta

Cucumaria frondosa - large northern sea cucumber

Class Echinoidea

Echinarachnius parma - sand dollar

Strongylocentrotus droebachiensis - green sea urchin

Class Stelleroidea

Subclass Asteroidea - sea stars or starfish

Asterias - common starfish

Henricia - blood starfish

Subclass Ophiuroidea - brittle stars

Amphipholis squamata - long-arm brittle star

Ophiopholis aculeata - daisy brittle star

Phylum Hemichordata - acorn worms

Saccoglossus kowalevskii

Phylum Chordata

Class Ascidiacea - sea squirts

Molgula - sea grapes

Tunicata A

Tunicata Unidentified - sea squirts

Phylum Unknown

Unknown Phylum - Leech?

Unknown Phylum - Platyhelminthes? - flatworms

APPENDIX 3

APPENDIX 3

SECTION 1

Taxa found at Sand Beaches. Numbers in columns are the numbers of stations at each location at which the taxon was recorded.	Kennebunkport	Scarborough	Reid-Georgetown	Pemaquid-Bristol	Lincolnville	Mt. Desert	Jonesport	Roque Bluffs
Total Number of Stations	8	8	8	8	8	8	8	8
Phylum Cnidaria								
Class Hydrozoa								
Hydrozoa Unidentified								1
Sertularia								2
Phylum Rhynchocoela								
Hemertea Unidentified		1		2				
Phylum Aschelminthes								
Nematoda Unidentified	1	1	3	4		4	2	1
Phylum Bryozoa								
Bryozoa Unidentified			1		1			
Bryozoa Encrusting						3		
Phylum Mollusca								
Class Gastropoda								
Subclass Prosobranchia								
Lacuna vincta				3				1
Littorina littorea				2	2	1		
Littorina obtusata			1					
Nassarius trivittata		1						
Odostomia	1						2	
Skeneopsis planorbis							1	
Thais lapillus						1		

	Kennebunkport	Scarborough	Reid-Georgetown	Pemaquid-Bristol	Lincolnville	Mt. Desert	Jonesport	Roque Bluffs
Class Bivalvia								
Mya arenaria				2		3		
Mytilus edulis				4		5		1
Phylum Annelida								
Class Polychaeta								
Family Phyllodocidae								
Eteone longa				1				
Family Glyceridae								
Glycera dibranchiata				1	2			
Family Nephtyidae								
Nephtys bucera	2	3		1				
Nephtys caeca				3	3			2
Nephtys longosetosa							1	
Nephtys picta					1			
Family Syllidae								
Exogone hebes				2				
Family Nereidae								
Nereis virens								1
Family Maldanidae								
Clymenella torquata				1				
Family Opheliidae								
Ophelia							6	
Family Spionidae								
Scolelepis squamata	2	2	1	1		1		

	Kennebunkport	Scarborough	Reid-Georgetown	Pemaquid-Bristol	Lincolnville	Mt. Desert	Jonesport	Rogue Bluffs
Family Spionidae								
Spiophanes bombyx				3				
Paraonis fulgens				3			3	2
Family Orbiniidae								
Orbinia		1						
Scoloplos				6				
Family Cirratulidae								
Cirratulus grandis				1				
Family Unknown								
Polychaeta Unidentified		1						
Class Oligochaeta								
Oligochaeta Unidentified	2	4	3	6	2	4	4	5
Phylum Arthropoda								
Subphylum Chelicerata								
Class Arachnid								
Arachnid Unidentified						1	1	3
Mite		1						
Subphylum Mandibulata								
Class Crustacea								
Subclass Cirripedia								
Balanus balanoides				1		1		
Subclass Malacostraca								
Order Cumacea								
Eudorella truncatula								2
Leptocuma minor						1		

	Kennebunkport	Scarborough	Reid-Georgetown	Pemaquid-Bristol	Lincolnville	Mt. Desert	Jonesport	Rogue Bluffs
Order Isopoda								
Chiridotea coeca		1	1					
Chiridotea tuftsi								2
Jaera sp.	1							
Order Amphipoda								
Family Gammaridae								
Gammarus oceanicus					1			
Family Haustoriidae								
Amphiporeia virginiana	7	6	6		1			
Acanthohaustorius millsi	3	6						
Haustorius canadensis	4	3	3					
Family Lysianassidae								
Psammonyx nobilis					2	2	2	2
Family Phoxocephalidae								
Harpinia propinqua				1				
Family Talitridae								
Orchestia platensis					1	1		
Talorchestia megalophthalma	2		2				2	2
Order Decapoda								
Carcinus maenas				1	1			
Class Insecta								
Insecta Adult		1				1	3	3
Insecta Larva							1	5
Insecta Pupa		1						1

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Appendix 3
Sand Beaches

	Kennebunkport	Scarborough	Reid-Georgetown	Pemaquid-Bristol	Lincolnville	Mt. Desert	Jonesport	Rogue Bluffs
Order Collembola								
Anurida Maritima		1				1		
Order Diptera								
Chaobrus			1					
Chironomid Larvae				1			2	
Dipteran Larvae						2		
Order Coleoptera								
Coleoptera Adult		1				1	1	
Order Hymenoptera								
Ant						1		
TOTAL OCCURRENCES	25	35	22	50	17	34	31	37
TAXA/SITE	10	17	10	22	11	18	14	18

Number of different organisms: 59

APPENDIX 3

SECTION 2

Taxa found at Sand Flats. Numbers in columns are the number of stations at each location at which the taxon was recorded.	Kittery	Wells	Heal Eddy,Georgetow	Rockport	Trescott Township
TOTAL NUMBER OF STATIONS	8	8	8	8	6
Phylum Cnidaria					
Class Hydrozoa					
Sertularia					1
Phylum Rhynchocoela					
Nemertea Unidentified	5		6	6	1
Phylum Aschelminthes					
Nematoda Unidentified	1	5	5	8	5
Phylum Mollusca					
Class Gastropoda					
Subclass Prosobranchia					
Hydrobia			3		
Lacuna vincta			1		
Littorina littorea		1	2	4	
Nassarius trivittata				2	
Odostomia bisuturalis				1	
Polinices heros	3		1		
Class Bivalvia					
Gemma gemma			4		
Macoma balthica	2	4	4	5	
Mya arenaria	1	6	5	3	1
Mytilus edulis		1	3	3	2

	Kittery	Wells	Heal Eddy Georgetown	Rockport	Trescott Township
Spisula solidissima				1	
Tellina agilis	3			4	
Phylum Annelida					
Class Polychaeta					
Family Phyllodocidae					
Eteone longa	1	1	4	4	1
Phyllodoce				1	
Family Sigalionidae					
Pholoe minuta			1		
Family Glyceridae					
Glycera dibranchiata			2	5	
Family Nephtyidae					
Aglaophamus verrilli	2				
Nephtys bucera	3				
Nephtys caeca	2	2	4	6	
Nephtys longosetosa					4
Family Syllidae					
Exogone hebes	1		3	4	6
Family Nereidae					
Nereis diversicolor	1			4	
Nereis virens		5	4		6
Family Capitellidae					
Capitella capitata	1				6
Heteromastus filiformis			1	6	

	Kittery	Wells	Heal Eddy, Georgetown	Rockport	Trescott Township
Family Maldanidae					
Clymenella torquata	2			3	
Maldanid	1				
Family Spionidae					
Polydora			5	1	
Polydora ligni			3		2
Pygospio elegans	6	2	2	6	4
Scolecolepides viridis		1	4	4	
Spio		1			
Spio filicornis	1				
Spio setosa					2
Spiophanes bombyx	2		4	5	
Streblospio benedicti			3	2	
Family Paraonidae					
Aricidea jeffreysii			3		
Paraonis fulgens			4	3	6
Family Lumbrinereidae					
Lumbrineris fragilis				1	
Family Orbiniidae					
Orbinia	2				1
Scoloplos	2		4	5	
Family Cirratulidae					
Tharyx acutus			4		
Family Sabellidae					
Fabricia sabella			2		

	Kittery	Wells	Heal Eddy. Georgetown	Rockport	Trescott Township
Family Unknown					
Polychaeta BB	1				
Class Oligochaeta					
Oligochaeta		4	5	5	5
Phylum Arthropoda					
Subphylum Mandibulata					
Class Crustacea					
Subclass Cirripedia					
Balanus balanoides				1	
Subclass Malacostraca					
Order Cumacea					
Leptocuma minor			1		
Order Isopoda					
Chiridotea coeca			1	1	6
Chiridotea tuftsi			1		5
Edotea triloba			1	1	
Idotea phosphorea	1				
Order Amphipoda					
Family Corophiidae					
Corophium insidiosum		1	1		
Corophium volutator			1	2	
Unciola irrorata	1				
Family Gammaridae					
Gammarus			1		
Gammarus lawrencianus			5		4
Gammarus oceanicus			1		

	Kittery	Wells	Heal Eddy, Georgetown	Rockport	Trescott Township
Family Haustoriidae					
Acanthohaustorius millsi	8		4		
Haustorius canadensis	4				
Protohaustorius deichmannae	7				
Family Ischyroceridae					
Jassa falcata			1		
Family Lysianassidae					
Psammonyx nobilis	5		5	3	4
Order Decapoda					
Carcinus maenas			1	3	
Crangon septemspinosa	2		2	1	
Class Insecta					
Insecta Larva					1
Order Hymenoptera					
Ant	1				
Phylum Hemichordata					
Saccoglossus kowalevskii	3				
Phylum Unknown - Leech?					1
TOTAL OCCURRENCES	75	34	122	114	74
TAXA/SITE	30	13	43	34	22

Total number of different organisms: 71

APPENDIX 3

SECTION 3

Taxa found at Mud Flats. Numbers in columns are the number of stations at each location at which the taxon was recorded.		Kittery	Mussel Cove, Falmouth	Hodgdon Cove, Boothbay Harbor	East Friendship	Addison
	Total number of stations	7	8	8	8	8
Phylum Platyhelminthes						
Platyhelminthes Unidentified				2		
Phylum Rhynchocoela						
Nemertea Unidentified			1	6	7	1
Phylum Aschelminthes						
Nematoda Unidentified		5	8	6	8	1
Phylum Mollusca						
Class Gastropoda						
Gastropoda Unidentified					1	
Subclass Prosobranchia						
Acmaea testudinalis				1		
Hydrobia			3	6	8	8
Littorina littorea		4	8	8	3	
Littorina obtusata				2		
Littorina saxatilis				3	1	
Nassarius obsoletus			2		3	
Odostomia bisuturalis					8	
Polinices triseriata					3	
Skeneopsis planorbis				1		

	Kittery	Mussel Cove, Falmouth	Hodgdon Cove, Boothbay Harbor	East Friendship	Addison
Class Bivalvia					
Ensis directus	2				
Gemma gemma			1	8	1
Macoma balthica	6	8	8	8	8
Modiolus demissus				1	
Mya arenaria	6	8	8	8	8
Mytilus edulis	4	3	6	4	3
Tellina agilis	5				
Phylum Annelida					
Class Polychaeta					
Family Phyllodocidae					
Eteone heteropoda			1		
Eteone longa	7	7	7	3	
Family Nephtyidae					
Nephtys caeca	4	5	3	4	1
Nephtys ciliata		1			
Nephtys incisa					1
Family Syllidae					
Exogone hebes	2				
Family Nereidae					
Nereis diversicolor		2			4
Nereis virens	7	5	7	5	5
Family Capitellidae					
Heteromastus filiformis	7	6	4	7	
Notomastus latericeus					8

	Kittery	Mussel Cove, Falmouth	Hodgdon Cove, Boothbay Harbor	East Friendship	Addison
Family Maldanidae					
Clymenella torquata	1			2	
Maldanid	1				
Family Spionidae					
Polydora	6	7	6	5	2
Polydora ligni		8	2	5	
Pygospio elegans		1	2	8	
Spio filicornis	2				
Streblospio benedicti	6	8	7	8	3
Family Lumbrinereidae					
Lumbrineris brevipes	6				
Ninoe nigripes	1	1			
Family Orbiniidae					
Scoloplos	7	6	8	8	5
Family Cirratulidae					
Tharyx acutus	1	7	4	4	
Family Ampharetidae					
Ampharete acutifrons	1				
Ampharete arctica		2		2	
Family Sabellidae					
Fabricia sabella				3	
Family Unknown					
Polychaeta A		1			
Class Oligochaeta					
Oligochaeta	7	8	8	8	3

	Kittery	Mussel Cove, Georgetown	Hodgdon Cove, Boothbay Harbo	East Friendshi	Addison
Phylum Sipuncula					
Sipunculida		1			
Phylum Arthropoda					
Subphylum Mandibulata					
Class Crustacea					
Subclass Ostracoda					
Ostracoda Unidentified	1		1	4	
Subclass Cirripedia					
Balanus balanoides	2	4	3	1	
Subclass Malacostraca					
Order Cumacea					
Leucon nasicoides	6		4		
Oxyurostylis smithi	4				
Order Tanaidacea					
Leptochelia rapax		1		2	
Order Isopoda					
Jaera	1		3	1	
Order Amphipoda					
Family Ampeliscidae					
Ampelisca abdita	4	1	3	1	
Family Aoridae					
Microdeutopus gryllotalpa	1				
Family Corophiidae					
Corophium volutator		8	6	2	7

	Kittery	Mussel Cove, Falmouth	Hodgdon Cove, Boothbay Harbor	East Friendship	Addison
Family Gammaridae					
Gammarus lawrencianus		2			
Gammarus mucronatus	1	2	2	1	
Gammarus oceanicus		3	4		
Marinogammarus finmarchicus			2		
Family Lysianassidae					
Psammonyx nobilis				1	
Family Phoxocephalidae					
Phoxocephalus holbolli	1	1			
Family Pontogeneiidae					
Pontogeneia inermis			1		
Family Talitridae					
Orchestia platensis	3			1	
Order Decapoda					
Carcinus maenas	4	6	1	4	
Crangon septemspinosa	2	2	3		
Class Insecta					
Insecta Larva					1
Order Diptera					
Ceratopogonidae		2	1	5	
Chaoborus			1		
Chironomid Larva		1		5	
Dipteran Larva				2	
Dipteran Pupa				1	
Order Coleoptera					
Coleoptera Adult					3

Order Hymenoptera					
Ant	1				
Unknown Phylum - Leech?			1		
TOTAL OCCURRENCES	129	150	151	176	73

Total number of different organisms: 75

TAXA/SITE	36	37	39	43	19

APPENDIX 3

SECTION 4

Taxa found at Gravel Beaches. Numbers in columns are the number of stations at each location at which the taxon was recorded.

	Kittery	Bailey Island	Friendship	Temple Heights	Mt. Desert	Machiasport	Perry
Total number of stations	8	8	8	8	8	8	8
Phylum Cnidaria							
Class Hydrozoa							
Hydrozoa Unidentified	2						
Sertularia	2			6	1	4	1
Phylum Platyhelminthes							
Platyhelminthes Unidentified			1		3		5
Phylum Phynchocoela							
Nemertea Unidentified	6	4	4	3	5	1	5
Phylum Aschelminthes							
Nematoda Unidentified	6	8	7	8	8	4	8
Phylum Bryozoa							
Bryozoa Encrusting	2					1	
Flustrellidra	1						
Phylum Mollusca							
Class Gastropoda							
Subclass Prosobranchia							
Acmaea testudinalis		4	2		2		
Crepidula convexa		1					
Crepidula fornicata			1				
Lacuna vincta		1			1		1
Littorina littorea		4	8	5	7		

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Gravel Beaches

	Kittery	Bailey Island	Friendship	Temple Heights	Mt. Desert	Machiasport	Perry
Littorina obtusata			1			1	1
Littorina saxatilis			3		1		4
Oenopota						1	
Onoba aculeus						3	3
Skeneopsis planorbis					1		
Thais lapillus		2	1		1		1
Class Bivalvia							
Anomia aculeata							1
Gemma gemma		3					
Hiatella arctica			1				
Macoma balthica		2	4				
Mya arenaria		6	5	1	4		
Mytilus edulis	1	3	5	4	8		6
Phylum Annelida							
Class Polychaeta							
Family Dinophilidae							
Dinophilus		1					
Family Phyllodocidae							
Eteone longa			3		1		
Phyllodoce mucosa			1				
Family Polynoidae							
Harmothoe imbricata		2	2				
Family Sigalionidae							
Pholoe minuta	1	1	1			1	
Family Glyceridae							
Glycera dibranchiata			1	2			

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Gravel Beaches

	Kittery	Bailey Island	Friendship	Temple Heights	Mt. Desert	Machiasport	Perry
Family Nephtyidae							
Nephtys caeca		1	2				
Nephtys picta				1			
Family Syllidae							
Exogone hebes						1	
Syllis				1			
Family Nereidae							
Nereis virens		2	5	1			
Family Capitellidae							
Capitella capitata				1			
Family Spionidae							
Polydora		1	1				
Polydora ligni			2				
Pygospio elegans					1		
Scolecolepides viridis				1			
Spionid			3	1			
Family Orbiniidae							
Naineris quadricuspida	1						2
Family Pectinariidae							
Pectinaria gouldii		1	2				
Pectinaria granulata					1		
Family Flabelligeridae							
Pherusa affinis				1			
Family Sabellidae							
Fabricia sabella							1
Family Serpulidae							
Spirorbis borealis		1					

	Kittery	Bailey Island	Friendship	Temple Heights	Mt. Desert	Machiasport	Perry
Family Unknown							
Polychaeta BB					1		1
Class Oligochaeta							
Oligochaeta Unidentified	8	8	8	8	8	8	8
Phylum Sipuncula							
Sipunculida							5
Phylum Arthropoda							
Subphylum Arachnida							
Arachnid Unidentified	2				1		1
Mite	1	2		2	5	1	6
Pseudoscorpion		2		1	3		
Subphylum Mandibulata							
Class Crustacea							
Subclass Cirripedia							
Balanus balanoides		6	5	4	6		
Subclass Malacostraca							
Order Cumacea							
Eudorella emarginata			1				
Order Isopoda							
Jaera	1	3	5	3	5		
Order Amphipoda							
Family Corophiidae							
Corophium volutator			1		1		
Unciola irrorata		1					

	Kittery	Bailey Island	Friendship	Temple Height	Mt. Desert	Machiasport	Perry
Family Gammaridae							
Gammarus duebeni				1			
Gammarus lawrencianus					1		
Gammarus oceanicus		2		3	1		1
Gammarus setosus					2		
Marinogammarus finmarchicus			3	1	1	1	
Marinogammarus obtusatus						2	
Marinogammarus stoerensis					1	1	
Family Hyalidae							
Hyale nilssoni				2	1		
Family Talitridae							
Orchestia grillus		1					
Orchestia platensis	7	2			2	2	2
Family Caprellidae							
Paracaprella tenuis				1			
Order Decapoda							
Carcinus maenas	1	4	6	2	1		
Crab Zoea		1					
Class Insecta							
Insecta Adult	4	1	1	2	1	1	5
Insecta Larva						5	4
Insecta Pupa				1	2	4	4
Order Gollembola							
Anurida maritima	5	2		1	1		
Order Dermaptera							
Earwig	4						

	Kittery	Bailey Island	Friendship	Temple Height	Mt. Desert	Machiasport	Perry
Order Trichoptera							
Trichoptera Larva	1	2	1	2	1		
Order Diptera							
Chironomid Larva	1	1		1	1	1	3
Dipteran Larva				2			
Dipteran Pupa		1					
Order Coleoptera							
Coleoptera Adult	1	1		1	2		1
Order Hymenoptera							
Ant	2				1		
Order Diplopoda							
Millipede				1			
Phylum Echinodermata							
Class Echinoidea							
Echinarachnius parma				1			
TOTAL OCCURRENCES	59	92	97	76	95	39	80
TAXA/SITE	21	38	34	35	38	16	25

Total number of different organisms: 84

APPENDIX 3

SECTION 5

Taxa found at Cobble Beaches. Numbers in columns are the number of stations at each location at which the taxa was recorded.	Kittery	Kennebunkport	Bailey Island	Owl's Head	Lincolnville	Mt. Desert	Lubec	Perry
Total number of stations	8	8	8	8	8	8	8	8
Phylum Cnidaria								
Class Hydrozoa								
Hydrozoa Unidentified				1				1
Sertularia	1		1	1			3	2
Class Anthozoa								
Bunodactis stella							1	
Edwardsia elegans				1				
Phylum Platyhelminthes								
Platyhelminthes Unidentified			2			6	2	5
Phylum Rhynchocoela								
Nemertea Unidentified	4	1	5		1	1		8
Phylum Aschelminthes								
Nematoda Unidentified	8	3	8	7	7	3	1	8
Phylum Bryozoa								
Bryozoa Encrusting				4	1	1		
Phylum Mollusca								
Class Gastropoda								
Subclass Prosobranchia								
Acmaea testudinalis			2	1			1	
Buccinum undatum			1					
Lacuna vincta	1					2		

	Kittery	Kennebunkport	Bailey Island	Owl's Head	Lincolnville	Mt. Desert	Lubec	Perry
Littorina littorea	2	2	7	6	6	2		
Littorina obtusata		1					3	1
Littorina saxatilis			3	2	1		1	6
Onoba aculeus			2					5
Skeneopsis planorbis	1					1		3
Thais lapillus			2	3	2	2	1	1
Class Bivalvia								
Anomia simplex				1				
Gemma gemma				1				
Hiatella arctica						1		
Macoma balthica		1	1					1
Mya arenaria		2	6	3	2			2
Mytilus edulis	4	1	8	7	3	7	2	6
Tellina agilis				1				
Phylum Annelida								
Class Polychaeta								
Family Phyllodocidae								
Eteone		1						
Eteone longa		3	1			1		
Eteone trilineata			1		2			
Phyllodoce			1					
Family Polynoidae								
Eucranta villosa	1							
Harmothoe imbricata			4		2			
Lepidonotus squamatus						1		

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Cobble Beaches

	Kittery	Kennebunkport	Bailey Island	Owl's Head	Lincolnville	Mt. Desert	Lubec	Perry
Family Sigalionidae								
Pholoe minuta	1		1			1		
Family Glyceridae								
Glycera dibranchiata					2			
Family Nephtyidae								
Nephtys bucera				1	1			
Nephtys caeca			1					
Nephtys incisa			1		1			
Nephtys picta			1					
Family Syllidae								
Exogone hebes								1
Family Nereidae								
Nereis	1							
Nereis succinea					2			
Nereis virens		3	2		4			
Family Arenicolidae								
Arenicola cristata		1						
Family Maldanidae								
Clymenella torquata		1	2					
Maldanopsis elongata			1					
Nichomache lumbricalis			1					
Family Spionidae								
Polydora		2	1		1			
Pygospio elegans			1					
Scolecolepides viridis					1			
Spio filicornis		1						

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Cobble Beaches

	Kittery	Kennebunkport	Bailey Island	Owl's Head	Lincolnville	Mt. Desert	Lubec	Perry
Spionid			1		1			
Spiophanes bombyx			1					
Family Orbiniidae								
Naineris quadricuspida								2
Scoloplos			1					
Family Pectinariidae								
Pectinaria gouldii				1	1			
Family Flabelligeridae								
Pherusa plumosa			1					
Family Sabellidae								
Fabricia sabella							1	1
Family Serpulidae								
Spirorbis borealis			2					
Family Unknown								
Polychaeta A			1					
Polychaeta CC		3						
Class Oligochaeta								
Oligochaeta Unidentified	7	7	8	7	7	7	4	8
Phylum Sipuncula								
Sipunculida			1					5
Phylum Arthropoda								
Subphylum Chelicerata								
Class Arachnida								
Arachnid Unidentified	1	1	1			1		
Mite	2		3			1	2	5
Pseudoscorpion	1		2					

	Kittery	Kennebunkport	Bailey Island	Owl's Head	Lincolnville	Mt. Desert	Lubec	Perry
Subphylum Mandibulata								
Class Crustacea								
Subclass Cirripedia								
Balanus balanoides		3	8	7	5	1		1
Subclass Malacostraca								
Order Cumacea								
Diastylis polita			1					
Eudorella emarginata			1					
Order Isopoda								
Edotea triloba					1			
Idotea phosphorea					1			
Jaera	2	4	7	3	6	3	1	2
Philoscia vittata								1
Order Amphipoda								
Family Ampithoidae								
Ampithoe rubricata					1			
Family Corophiidae								
Corophium insidiosum		2	1					
Family Gammaridae								
Gammarus oceanicus	1	1	1			1	2	1
Gammarus setosus					1	2	3	
Marinogammarus finmarchicus		2	1	7	7			
Marinogammarus obtusatus			1					
Marinogammarus stoerensis						6	5	
Family Hyalidae								
Hyale nilssoni			2					

	Kittery	Kennebunkport	Bailey Island	Owl's Head	Lincolnville	Mt. Desert	Lubec	Perry
Family Talitridae								
Orchestia Platensis	7	8	3		2	2		3
Order Decapoda								
Cancer irroratus			2					
Carcinus maenas	3	4	5	6	5			
Crab Megalops		1						
Crab Zoea	1	2						
Pagurus							1	
Class Insecta								
Insecta Adult	2		1				3	5
Insecta Larva								3
Insecta Pupa		1						1
Order Collembola								
Anurida maritima	7	1	2					
Order Dermaptera								
Earwig	2	3						
Order Trichoptera								
Tricoptera Larva	5	1	1					1
Order Diptera								
Ceratopogonidae			1					
Chironomid Larva			1			1		7
Chironomid Pupa								1
Dipteran Larva			2					
Dipteran Pupa			1					
Order Coleoptera								
Coleoptera Adult	1							4

Order Hymenoptera								
Ant	1							
Order Chilopoda								
Centipede			1					
Phylum Echinodermata								
Class Echinoidea								
Strongylocentrotus droenbachiensis			1	2	2			
Class Stelleroidea								
Subclass Asteroidea								
Asterias					1			
Phylum Chordata								
Class Ascidiacea								
Molgula				2				
Phylum Unknown					1			
Phylum Unknown - Platyhelminthes?						3		
TOTAL OCCURRENCES	67	67	133	75	81	57	37	101
TAXA/SITE	25	30	59	23	32	24	18	31

Total number of different organisms: 104

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SECTION 6

Taxa found at Boulder Beaches. Numbers in columns are the number of stations at each location at which the taxa was recorded.

Taxa	Wells	Bailey Island	St. George	Lincolnville	Mt. Desert	Roque Bluffs
Total Number of Stations	6	8	8	6	6	6
Phylum Porifera						
Porifera Unidentified						1
Phylum Cnidaria						
Class Hydrozoa						
Hydrozoa Unidentified	1				3	
Sertularia	3	4	1		3	4
Class Anthozoa						
Anthozoan Unidentified					1	3
Bunodactis stella					1	1
Phylum Platyhelminthes						
Platyhelminthes Unidentified	3	1	1	1	2	5
Phylum Rhynchocoela						
Nemertea Unidentified	3	5	4	4	4	6
Phylum Aschelminthes						
Nematoda Unidentified	6	8	6	5	6	6
Phylum Bryozoa						
Bryozoa Unidentified			2		2	
Bryozoa Encrusting	2	4	2	1	3	
Flustrellidra					1	2
Phylum Mollusca						

	Wells	Bailey Island	St. George	Lincolnville	Mt. Desert	Rogue Bluffs
Class Polyplacophora						
Tonicella Marmorea					2	
Class Gastropoda?						
Gastropoda Unidentified					1	
Subclass Prosobranchia						
Acmaea testudinalis	4	2	2	2	3	2
Lacuna vincta	1				2	
Littorina littorea	4	7	3	5	4	2
Littorina obtusata	4	6	5	1	3	6
Littorina saxatilis	4	4	5	4	3	5
Margarites helicina	1				2	1
Onoba aculeus	1	2	1		2	4
Skeneopsis planorbis						4
Thais lapillus	2	4	4	1	4	6
Subclass Opisthobranchia						
Ancula gibbosa					2	
Denronotus frondosus					1	
Doto coronata					1	
Onchidoris aspersa					2	
Onchidoris fusca			1			
Class Bivalvia						
Anomia aculeata	1				1	
Anomia simplex		3			2	
Crenella decussata		1				
Crenella faba					1	
Crenella glandula			1			

	Wells	Bailey Island	St. George	Lincolnville	Mt. Desert	Roque Bluffs
Class Bivalvia (cont.)						
Gemma gemma		2				
Hiatella arctica	2	3	1		3	
Modiolus modiolus	1	3		1	1	1
Mya arenaria	2	1	2		4	5
Mytilus edulis	6	6	5	6	6	3
Petricola pholadiformis	1					
Spisula solidissima	1					
Phylum Annelida						
Class Polychaeta						
Family Phyllodocidae						
Eteone			1			
Eteone longa	1				2	
Eteone trilineata			1			
Eumida sanguinea					1	
Phyllodoce		1				
Phyllodoce groenlandica					1	
Phyllodoce maculata					1	
Phyllodocid					1	
Family Polynoidae						
Harmothoe				1		
Harmothoe imbricata			1		2	
Lepidonotus squamatus	1				2	
Polynoid Juvenile					1	
Family Sigalionidae						
Pholoe minuta		1		1	2	

	Wells	Bailey Island	St. George	Lincolnville	Mt. Desert	Roque Bluffs
Family Hesionidae						
Microphthalmus sczelkowii						2
Family Syllidae						
Autolytus					1	1
Exogone verugera					1	
Syllidae					3	
Syllid A	1					
Syllid B	1					
Syllis gracilis					1	
Family Nereidae						
Nereis	1				2	
Nereis diversicolor		1				
Nereis succinea			1			
Nereis virens	3		2	2		1
Family Spionidae						
Polydora	1				2	
Spionid					1	
Family Paraonidae						
Paraonis fulgens			1		2	
Family Orbiniidae						
Orbinia					2	
Naineris quadricuspida						3
Family Cirratulidae						
Cirratulus cirratus					1	
Tharyx					1	

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	Wells	Bailey Island	St. George	Lincolnville	Mt. Desert	Rogue Bluffs
Family Ampharetidae						
Ampharete arctica					1	
Ampharetid sp. A					1	
Ampharetid sp. B					1	
Ampharetid sp. C					1	
Family Terebellidae						
Amphitrite cirrata					2	
Amphitrite johnstoni					1	1
Loimia					1	
Nicolea					2	
Pista cristata					1	
Polycirrus					2	
Terebellidae					1	
Family Sabellidae						
Fabricia sabella	5				2	2
Myxicola infundibulum					1	
Family Serpulidae						
Spirorbis borealis	3	3			2	
Family Unknown						
Polychaeta BB	1					
Polychaeta Unidentified	1					
Class Oligochaeta						
Oligochaeta	6	8	8	6	6	6
Phylum Sipuncula						
Sipunculida		4			1	

	Wells	Bailey Islan	St. George	Lincolnville	Mt. Desert	Rogue Bluffs
Phylum Arthropoda						
Subphylum Pycnogonida						
Achelia spinosa					1	
Nymphon grossipes					1	
Phoxichilidium femoratum	1				1	2
Pycnogonum Littorale		1				
Subphylum Chelicerata						
Class Arachnida						
Arachnid Unidentified					2	
Mite	4		3		2	5
Subphylum Mandibulata						
Class Crustacea						
Subclass Cirripedia						
Balanus balanoides	6	6	5	5	5	2
Subclass Malacostraca						
Order Tanaidacea						
Leptognatha		1				
Order Isopoda						
Chiridotea coeca		1				
Idotea balthica		2				
Jaera	6	6	5	4	5	5
Order Amphipoda						
Family Ampithoidae						
Ampithoe rubricata	2	2	2		1	3
Family Calliopidae						
Calliopius laeviusculus					1	

	Wells	Bailey Island	St. George	Lincolnville	Mt. Desert	Rogue Bluffs
Family Corophiidae						
Corophium insidiosum					2	
Family Dexaminidae						
Dexamine thea					2	
Family Gammaridae						
Gammaridae		2		1		
Gammarus duebeni				3		
Gammarus oceanicus	1	4	3	3	2	2
Gammarus setosa						2
Marinogammarus finmarchicus	2	3	3			2
Marinogammarus obtusatus	2	6	2		2	4
Marinogammarus stoerensis	2	4	2	4	2	1
Family Hyalidae						
Hyale nilssoni	6	7	4		2	1
Family Ischyroceridae						
Ischyrocerus anguipes					2	
Jassa falcata	2	2			2	
Family Pontogeneiidae						
Pontogeneia inermis					2	
Family Talitridae						
Orchestia		1				
Orchestia grillus			1			
Orchestia platensis	2		2			
Family Caprellidae						
Luconacia			1			
Aeginina longicornis					1	

	Wells	Bailey Island	St. George	Lincolnville	Mt. Desert	Roque Bluffs
Order Decapoda						
Cancer irroratus		2		1		
Carcinus maenas	4	7	8	5	5	3
Hyas coarctatus					1	
Class Insecta						
Insecta Adult			1			
Order Collembola						
Anurida maritima	5	1				
Order Dermaptera						
Earwig	1					
Order Diptera						
Ceratopogonidae					1	
Chironomid Larva		4	1			4
Chironomid Pupa						2
Dipteran Larva	1	1	3		1	1
Dipteran Pupa			1			
Order Hymenoptera						
Ant	1				1	
Phylum Echinodermata						
Class Holothuroidea						
Chiridota laevis					1	
Cucumaria frondosa					1	
Class Echinoidea						
Strongylocentrotus droebachiensis	2	2		1	2	

Class Stelleroidea						
Subclass Asteroidea						
Asterias					2	
Henricia					2	
Subclass Ophiuroidea						
Amphipholis squamata					1	
Ophiopholis aculeata	1		1			
Phylum Chordata						
Class Ascidiacea						
Molgula	1				2	
Tunicata A					1	
Tunicata Unidentified					1	
Phylum Unknown		2			2	
Phylum Unknown - Leech?					1	1
TOTAL OCCURRENCES	130	151	110	68	196	123
TAXA SITE	53	46	43	24	103	42

Total number of different organisms: 144

APPENDIX 3

SECTION 7

Taxa found at Low-Energy Rocky Shores. Numbers in columns are the number of stations at each location at which the taxon was recorded.

	E. Harpswell	Boothbay Harbor	Waldoboro	Mt. Desert	Machiasport
Total number of stations	6	8	8	6	6
Phylum Cnidaria					
Class Hydrozoa					
Hydrozoa Unidentified	1		2	2	
Sertularia	4	4	2		
Class Anthozoa					
Bunodactis stella					1
Phylum Platyhelminthes					
Platyhelminthes Unidentified		1		1	2
Phylum Rhynchocoela					
Nemertea Unidentified	4	2	4	3	5
Phylum Aschelminthes					
Nematoda Unidentified	4	5	3	3	4
Phylum Bryozoa					
Bryozoa Unidentified	1				
Bryozoa Encrusting	1	1	1		
Flustrellidra		1			
Phylum Mollusca					
Class Gastropoda					
Subclass Prosobranchia					
Acmaea testudinalis	1	1	2	1	5
Crepidula fornicata			1		

	E. Harpswell	Boothbay Harbor	Waldoboro	Mt. Desert	Machiasport	Dennysville
Subclass Prosobranchia (cont.)						
Littorina littorea	6	6	6	5	7	2
Littorina obtusata	6	5	6	2	6	6
Littorina saxatilis	2	2			6	6
Onoba aculeus	2				2	6
Polinices heros						1
Skeneopsis planorbis				1	3	3
Thais lapillus	1	1	3		4	1
Subclass Opisthobranchia						
Onchidoria		1				
Class Bivalvia						
Anomia aculeata	1					
Anomia simplex	1		1			
Bivalve D	1					
Gemma gemma			1			
Hiatella arctica	1	1	1			
Mya arenaria	2	3	3			4
Mytilus edulis	5	4	3	5	2	3
Phylum Annelida						
Class Polychaeta						
Family Phyllodocidae						
Eteone longa	1					
Phyllodoce arenae	1					
Family Polynoidae						
Harmothoe imbricata		1	1			
Polynoid		1				

	E. Harpswell	Boothbay Harbor	Waldoboro	Mt. Desert	Machiasport
Family Syllidae					
Syllidae				2	
Family Nereidae					
Nereis virens	1	2	2		
Family Spionidae					
Polydora		1		2	
Polydora ligni	1		1		
Family Terebellidae					
Amphitrite johnstoni		1			
Family Flabelligeridae					
Diplocirrus hirsutus			1		
Pherusa			1		
Family Sabellidae					
Fabricia sabella				2	1
Family Serpulidae					
Spirorbis borealis	3	4	2		
Class Oligochaeta					
Oligochaeta	4	5	5	3	6
Phylum Arthropoda					
Subphylum Chelicerata					
Class Arachnida					
Arachnid Unidentified				1	
Mite	2	1	1	3	1
Pseudoscorpion	1				

	E. Harpswell	Boothbay Harbor	Waldoboro	Mt. Desert	Machiasport
Subphylum Mandibulata					
Class Crustacea					
Subclass Cirripedia					
Balanus balanoides	6	6	6	6	6
Balanus balanus		1			
Balanus crenatus	2				
Subclass Malacostraca					
Order Isopoda					
Jaera	6	4	5	3	4
Philoscia vittata					2
Order Amphipoda					
Family Ampithoidae					
Ampithoe rubricata	4	2	2		1
Family Corophiidae					
Corophium insidiosum	1	1	3		
Family Dexaminidae					
Dexamine thea		1			
Family Gammaridae					
Gammarus oceanicus	1		1		
Marinogammarus finmarchicus	3	2	3		1
Marinogammarus obtusatus	3	3	3	2	4
Marinogammarus stoerensis	1		2		
Family Hyalidae					
Hyale nilssoni	4	3	2	1	3
Family Caprellidae					
Aeginina longicornis			1		

	E. Harpswell	Boothbay Harbor	Waldoboro	Mt. Desert	Machiasport	Dennysville
Order Mysidacea						
Mysid		1				
Order Decapoda						
Carcinus maenas	6	6	3	1	1	
Class Insecta						
Order Collembola						
Anurida maritima	5	2	4			
Order Dermaptera						
Earwig					1	
Order Diptera						
Chironomid Larva	4	2	2	1	1	5
Chironomid Pupa						3
Dipteran Larva					1	1
Dipteran Pupa					1	
Class Diplopoda						
Millipede			1			
Phylum Echinodermata						
Class Stelleroidea						
Subclass Asteroidea						
Asterias	2	3				2
Phylum Unknown - Leech?					1	
TOTAL OCCURRENCES	106	91	91	50	82	117
TAXA/SITE	40	37	37	21	28	37

Total number of different organisms:

APPENDIX 3

SECTION 8

Taxa found at High-Energy Rocky Shores. Numbers are the number of stations at each location at which the taxon was recorded.

Taxon	Bailey Island
Phylum Cnidaria	
Class Hydrozoa	
Hydrozoa Unidentified	1
Sertularia	4
Phylum Platyhelminthes	
Platyhelminthes Unidentified	3
Phylum Rhynchocoela	
Nemertea Unidentified	2
Phylum Aschelminthes	
Nematoda Unidentified	5
Phylum Bryozoa	
Bryozoa Unidentified	1
Bryozoa Encrusting	2
Flustrellidra	2
Phylum Mollusca	
Class Gastropoda	
Subclass Prosobranchia	
Acmaea testudinalis	4
Lacuna vincta	3
Littorina littorea	4
Littorina obtusata	4
Littorina saxatilis	4
Margarites helicina	2

	Bailey Island
Subclass Prosobranchia (cont.)	
Onoba aculeus	2
Skeneopsis planorbis	2
Thais lapillus	5
Class Bivalvia	
Anomia aculeata	2
Anomia simplex	2
Hiatella arctica	2
Modiolus modiolus	1
Mya arenaria	3
Mytilus edulis	6
Phylum Annelida	
Class Polychaeta	
Family Phyllodocidae	
Eteone	1
Eteone longa	1
Eteone trilineata	1
Phyllodoce	1
Phyllodoce maculata	1
Phyllodocid	1
Family Polynoidae	
Lepidonotus squamatus	2
Family Nereidae	
Nereis virens	2
Family Capitellidae	
Capitella capitata	1

	Bailey Island
Family Spionidae	
Polydora	1
Family Orbiniidae	
Orbinia	1
Family Terebellidae	
Polycirrus	1
Family Sabellidae	
Fabricia sabella	2
Family Serpulidae	
Spirorbis borealis	2
Class Oligochaeta	
Oligochaeta	3
Phylum Arthropoda	
Subphylum Chelicerata	
Class Arachnida	
Arachnid Unidentified	1
Mite	3
Subphylum Mandibulata	
Class Crustacea	
Subclass Cirripedia	
Balanus balanoides	5
Balanus balanus	1
Subclass Malacostraca	
Order Isopoda	
Idotea phosphorea	2
Jaera	5

	Bailey Island
Order Amphipoda	
Family Ampeliscidae	
Ampelisca vadorum	1
Family Ampithoidae	
Ampithoe rubricata	3
Family Calliopidae	
Calliopius	1
Family Corophiidae	
Corophium insidiosum	2
Family Dexaminidae	
Dexamine thea	1
Family Gammaridae	
Gammarellus angulosus	2
Gammarus oceanicus	2
Marinogammarus obtusatus	2
Marinogammarus stoerensis	1
Family Hyalidae	
Hyale nilssoni	5
Family Ischyroceridae	
Jassa falcata	3
Family Caprellidae	
Caprella penantis	1
Order Decapoda	
Cancer irroratus	3
Carcinus maenas	3

	Bailey Island
Class Insecta	
Order Collembola	
Anurida maritima	2
Order Diptera	
Chironomid Larva	3
Phylum Echinodermata	
Class Echinoidea	
Strongylocentrotus droebachiensis	1
Class Stelleroidea	
Subclass Asteroidea	
Asterias	2
Phylum Chordata	
Class Ascidiacea	
Molgula	2
TOTAL OCCURRENCES	144
TAXA/SITE	63

APPENDIX 3
SECTION 9

Taxa identified at high-energy rocky shore sites during a qualitative survey for the Critical Areas Program.

Species List Critical Areas Study August 1977 High Energy-Bedrock Substrate Total No. Taxa - 61 (plus 1 fish) 1 = High Intertidal Zone 2 = Barnacle Zone 3 = Rockweed Zone 4 = *Chondrus* Zone	Hoyt Neck Biddeford	Two Lights Cape Elizabeth	Cape Newagen Southport	Ocean Point Boothbay	Pemaquid Point Bristol	Port Clyde St. George	Seal Harbor Mt. Desert	Schoodic Point Winter Harbor	Petit Manan Steuben	McClellan Park Millbridge	Great Wass Island Beals	Roque Bluffs
Phylum Porifera												
Halichondria panicea	4	4	34	4	34	3	34	4	4	34	34	34
Unidentified Porifera				4								
Phylum Cnidaria												
Class Hydrozoa												
Sertularia	34	4	3	34	34	3	34	4	4	3	34	3
Unidentified Hydrozoa	4	4		34			4			4		
Class Anthozoa												
Anemone A	4	4			34					34		
Metridium senile			4									
Phylum Platyhelminthes												
Notoplana atomata		34		4		4	4			3		
Unidentified Platyhelminthes		4	3	34	4		4					
Phylum Rhychocoela												
Nemertea		34	34	4	23	4	4	4	234		4	
Phylum Aschelminthes												
Nematoda	24	234	234	4	234	24	234	234	234	234	3	23
Phylum Bryozoa												
Encrusting Bryozoa	4		34	34	3	34	4	4	4	34	3	34
Erect Bryozoa							4		4			
Flustrellidra	4			34		34	4		4	4	34	3

List of taxa, page 2 Critical Areas Study
August 1977
High-Energy Bedrock Substrate
Total No. Species - 61 (plus 1 fish)

1 = High Intertidal Zone
2 = Barnacle Zone
3 = Rockweed Zone
4 = *Chondrus* Zone

	Hoyt Neck Biddeford	Two Lights Cape Elizabeth	Cape Newagen Southport	Ocean Point Boothbay	Pemaquid Point Bristol	Port Clyde St. George	Seal Harbor Mt. Desert	Schoodic Point Winter Harbor	Petit Manan Steuben	McClellan Park Millbridge	Great Wass Is. Beals	Roque Bluffs
Phylum Mollusca												
Class Polyplacophora												
Tonicella marmorea		4	4	4	4	4			4	4	4	
Unidentified Chiton				2			34					
Class Gastropoda												
Acmaea testudinalis	3	234	34	34	234	34	34	34	1234	34	34	234
Aeolida papillosa				4	34					4		
Dendronotus frondosus										34	4	
Lacuna vincta	4	4	4	4	4	3	4	4	4	4	4	4
Littorina littorea	234	1234	134	1234	4	1234	3	34	234	34	34	3
Littorina obtusata	4	234	3		34	3	23	34	4	23	34	3
Littorina saxatilis	1	12	12		123	1	12	123	123	123	13	123
Margarites helicina				4			4	4				
Thais lapillus	34	234	234	234	234	234	234		34	234	3	234
Velutina laevigata											4	
Class Bivalvia												
Anomia simplex	4		3	4		3	34		4	4		
Hiatella arctica	24	4	34	4	234	34	34	4	4	4	34	
Modiolus modiolus	34	3	34	4	3	34	34	34	34	3	34	3
Musculus niger									4			
Mytilus edulis	24	1234	234	1234	234	1234	1234	234	1234	1234	3	23

List of taxa, page 3 Critical Areas Study
August 1977
High-Energy Bedrock Substrate
Total No. Species - 61 (plus 1 fish)

1 = High Intertidal Zone
2 = Barnacle Zone
3 = Rockweed Zone
4 = *Chondrus* Zone

	Hoyt Neck Biddeford	Two Lights Cape Elizabeth	Cape Newagen Southport	Ocean Point Boothbay	Pemaquid Point Bristol	Port Clyde St. George	Seal Harbor Mt. Desert	Schoodic Point Winter Harbor	Petit Manan Steuben	McClellan Park Millbridge	Great Wass Is. Beals	Roque Bluffs
Phylum Annelida												
Class Polychaeta												
Autolytus						4						
Harmothoe imbricata				4	4			4		4		
Lepidonotus squamata	4	4	34	4	34	34	4	4	4	4	4	
Nereis pelagica					4						4	
Nereis virens							4		4			
Paranaitis	4											
Spirorbis borealis	3			4							4	
Spirorbis spirillium											4	
Unidentified Scaleworm									4			
Class Oligochaeta												
Oligochaeta	24	234	234	1234	234	4	234	234	234	234	3	23
Phylum Arthropoda												
Class Arachnida												
Mite	1		4	4	4		1					
Class Crustacea												
Subclass Cirripedia												
Balanus balanoides	123	1234	123	1234	1234	123	1234	234	1234	1234	13	23
Subclass Malacostraca												
Order Isopoda												
Idotea balthica		4		4				4		4		
Jaera	2		4	2		3	34		1	1		

List of taxa, page 4 Critical Areas Study
August 1977
High-Energy Bedrock Substrate
Total No. Species - 61 (plus 1 fish)

1 = High Intertidal Zone
2 = Barnacle Zone
3 = Rockweed Zone
4 = *Chondrus* Zone

	Hoyt Neck Biddeford	Two Lights Cape Elizabeth	Cape Newagen Southport	Ocean Point Boothbay	Pemaquid Point Bristol	Port Clyde St. George	Seal Harbor Mt. Desert	Schoodic Point Winter Harbor	Petit Manan Steuben	McClellan Park Millbridge	Great Wass Is. Beals	Roque Bluffs
Order Amphipoda												
Ampithoe rubricata	4		4	4			34		4	34	4	34
Gammarellus angulosus	4	4	4		4	4		34	4	34	4	34
Gammarus oceanicus			2	4	4		34	34			4	34
Hyale nilssoni	23	2	123	23	23	23	2	123	12	13	3	
Jassa falcata			4	2								
Marinogammarus obtusatus				3								
Unidentified Amphipoda					4							
Superorder Eucarida												
Order Decapoda												
Cancer irroratus	4	4	4	4				4	4	4		
Carcinus maenas	34	34	34	34	4	3	3	34	3	34	3	
Pagurus acadianus	4					4			4			
Class Insecta												
Anurida maritima	1	12	1	1	1	12		1				
Phylum Echinodermata												
Asterias forbesii			4									
Asterias vulgaris	4	34	34	4	34	34	4	4	4	4	34	
Henricia	4		4	4					4			
Ophiopholis aculeata	4	4	4		34	4					4	
Strongylocentrotus droenbachiensis	34	34	34	4	34	4	3				4	
Phylum Chordata												
Class Ascidiacea												
Amaroucium										4		
Class Pisces												
Pholis gunnelus				4					4	4		

APPENDIX 3

SECTION 10

Taxa found at the Cousins River salt marsh, Yarmouth. Numbers are the number of stations at which the taxon was recorded.

	Cousins River, Yarmouth
Phylum Rhynchocoela	
Nemertea Unidentified	2
Phylum Aschelminthes	
Nematoda Unidentified	4
Phylum Mollusca	
Class Gastropoda	
Gastropoda Unidentified	1
Subclass Prosobranchia	
Hydrobia	4
Littorina littorea	1
Littorina saxatilis	3
Subclass Pulmonata	
Melampus bidentatus	1
Class Bivalvia	
Macoma balthica	3
Mya arenaria	3
Phylum Annelida	
Class Polychaeta	
Family Nereidae	
Nereis diversicolor	4
Family Capitellidae	
Capitella capitata	3

	Cousins River, Yarmouth
Family Spionidae	
Polydora	2
Pygospio elegans	1
Class Oligochaeta	
Oligochaeta Unidentified	6
Phylum Arthropoda	
Subphylum Chelicerata	
Class Arachnida	
Arachnid Unidentified	1
Mite	2
Subphylum Mandibulata Class Crustacea Subclass Malacostraca	
Order Tanaidacea	
Leptochelia rapax	1
Order Isopoda	
Edotea triloba	2
Jaera	1
Order Amphipoda	
Family Corophiidae	
Corophium volutator	3
Family Ischyroceridae	
Jassa falcata	1
Family Talitridae	
Orchestia grillus	2
Orchestia uhleri	1

	Cousins River, Yarmouth
Class Insecta	
Insecta Adult	2
Order Diptera	
Ceratopogonidae	4
Chironomid Larva	2
Dipteran Larva	2
Order Coleoptera	
Coleoptera Adult	1
TOTAL	63

Total number of different organisms: 28

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GLOSSARY

Acclimate - physiological compensation by a living organism to changes in the environment.

Amphipod - member of the Order Amphipoda. These small crustaceans have laterally compressed bodies and legs specialized for both swimming and walking. Many species of this ecologically important group live along the Maine coast. They are commonly called beach hoppers or scuds.

Annelid - any worm belonging to the Phylum Annelida. There are three major classes, consisting of the polychaetes, oligochaetes, and leeches. They are characterized by a definite head and a body of many segments. Sand worms and earthworms are examples.

Anoxic - free of oxygen. An anoxic layer of sediment is that layer in which no oxygen is available for aerobic respiration. The black layer just under the surface of a mud flat is an example of an anoxic sediment.

Ascidian - members of the Phylum Chordata. Shaped like a wine skin with two spouts or siphone through which water enters or exits in the process of being filtered for food.

Barnacle - crustaceans adapted to a sessile existence by secreting a shell around a reduced body form consisting of a mouth, a digestive tract, and six pairs of legs that may be extended through the top of the shell to filter the water for food.

Benthic - of, relating to, or occurring at the bottom of a body of water.

Benthos - the bottom of a body of water or the organisms living there.

Biocide - an agent used to destroy life, such as a herbicide or pesticide.

Bioindex - a numerical ranking of a species according to its abundance within a collection of organisms.

Biomagnification - the process by which substances, usually toxic substances like DDT, become concentrated in the flesh of animals high on a food chain through their feeding on contaminated plants and animals.

Bryozoa - a phylum made up of very small colonial animals that live on rocks, algae, shells, wharf pilings, etc. Some colonies are branched or unbranched stalks and some are encrusting.

Byssal - tough, horny threads secreted by some bivalves, such as mussels, to attach the animal to a substratum.

Class - a major subdivision of a phylum, e.g., bivalves and gastropods are classes of the Phylum Mollusca.

Community - a group of organisms occurring in a particular environment, presumably interacting with each other and with the environment and separable by means of ecological survey from other groups.

Cumacean - small shrimp-like crustaceans ranging from 5 to 15 mm in length; head and anterior portion of the thorax are covered by a short, hard, shell; abdomen is long, slender, cylindrical and segmented.

Deposit Feeder - benthic animals which feed discriminantly or indiscriminantly on organic matter in or on the sediment.

Detritus - generally any dead organic material. In the coastal zone the major sources of detritus are marsh plants and algae.

Diatom - a planktonic, unicellular, or colonial form of algae with a skeletal wall of silica. Diatoms are the major producers in marine systems.

Diversity - having richness and variety. A high-diversity community has many species, and a low-diversity community has few species.

Echinoderm - a marine phylum of organisms characterized by spiny skin, five-part radial symmetry, and a water-vascular system which is responsible for movement through changes in hydraulic pressure within a canal system, i.e. starfish, brittle stars, sea urchins, sea cucumbers.

Epifauna - animals living on the bottom of a body of water as opposed to in the bottom.

Family - subdivision of an order. An intermediate level of classification of organisms between order and genus.

Fauna - animals or the animal life of a specified environment, region, or period.

Fecal Pellets - compacted and well-formed end products or wastes of animal digestion.

Fission - reproduction by the division of the body into 2 or more parts, each of which grows into a similar complete organism.

Gamete - a mature germ cell, i.e., an egg or sperm.

Gastropod - a snail which belongs to the Class Gastropoda of the Phylum Mollusca.

Genera - a subdivision of a family, which includes closely related species. The plural form of genus.

Heavy Metal - a metal of high specific gravity. Many heavy metals, such as mercury, cadmium, copper etc. can be serious pollutants in aquatic systems.

Herbivore - an animal which consumes living plant material.

Hermaphroditic - having both male and female reproductive organs.

Infauna - the fauna which lives in the sediment of the bottom of a body of water.

Flora - plants or plant life of a specified environment, region, or period.

Hydroid - a member of the Class Hydrozoa of the Phylum Cnidaria. These small animals exhibit alternation of generations, that is one generation is an attached benthic form and the next is a free-floating, jelly-fish-like organism.

Intertidal - area between extreme high and extreme low tidal marks.

Larva - the early form of an animal that at birth or hatching is fundamentally unlike its parent and must metamorphose before assuming the adult characteristics.

Littoral - that area above the mean low water mark which is directly under the influence of the sea.

Mollusc - any animal of the Phylum Mollusca characterized by a soft, unsegmented body that is usually protected by a calcareous shell, i.e., clams, snails, chitons, tusk shells, squid, and octopi.

Neap Tide - a tide of minimum range occurring at the first and third quarters of the moon.

Nitrate - the main source of nitrogen for most plants; NO_3.

Nutrient - an inorganic substance needed for plant growth, such as nitrate.

Oligochaete - annelids belonging to the Class Oligochaeta. The group includes the earthworms and is characterized by the lack of lateral appendages on each segment.

Osmotic - refers to the tendency of water to move across a semipermeable membrane in response to differences in solute concentrations.

Pelagic - of, relating to, or living or occurring in the water column, as opposed to on the bottom.

Pheromone - a substance excreted by an animal which influences the behavior of other individuals of the same species.

Phylum - the primary subdivision of the animal kingdom.

Phytoplankton - those plants that drift with water currents, such as diatoms.

Planktonic - relating to organisms which drift with the water currents with little or no capacity for directed movements.

Polychaete - annelids that belong to the Class Polychaeta; characterized by lateral appendages on each segment, i.e., sand worm.

Population - a group of individuals of the same species that are free to interbreed with one another.

Proboscis - a muscular, protrusible organ usually associated with the mouth of polychaetes and other groups. Used in capturing prey or feeding.

Siphon - a muscular tube through which water passes for respiratory and/or feeding purposes. The "neck" of a clam is a siphon.

Taxa - the plural of taxon, a taxonomic unit or category.

Species - a category of plants and animals with distinctive characteristics in which organisms may interbreed with others of their kind and pass on these characteristics to their offspring.

Spring Tide - a tide of nearly maximum range between the high and low tidal marks that occurs around the time of the new and full moon, when the gravitational pull of the sun and moon are in the same direction.

Subtidal - referring to the subtidal environment; that area of the ocean never exposed to the atmosphere.

Suspension Feeder - animals that filter suspended organic matter from the water.

Tanaid - a very small crustacean belonging to the Order tanaidacea characterized by a rounded body compressed from top to bottom; a shell covers the head and the anterior portion of thorax, and the abdomen is segmented.

Tide - the alternate rising and falling of the surface of the ocean that usually occurs twice a day and is caused by the gravitational pull of the sun and moon.

Whelk - a common, relatively large, carnivorous subtidal gastropod mollusc.